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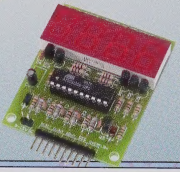

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SILICON CHIP'S

Electronics TestBench

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Where To Buy Kits & PC Boards

Many of the projects described in this publication are available as complete kits of parts from several electronics retailers. In particular, try Altronics, Dick Smith Electronics, Jaycar Electronics and Oatley Electronics.

The PC boards (but not for the Telephone Exchange Simulator) can be ordered separately from RCS Radio, 41 Arlewis St, Chester Hill 2162. Phone (02) 9738 0330.

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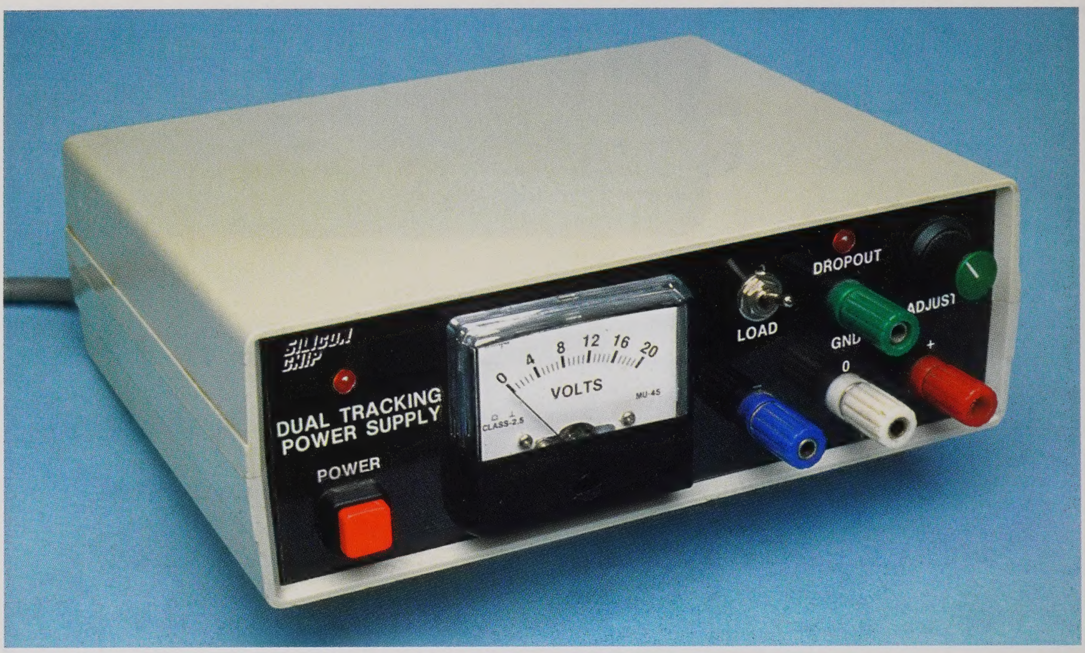


A dual tracking ±18.5V power supply

This low-cost dual tracking power supply is capable of providing up to ±18.5V DC. It features a voltage meter, a LED dropout indicator & short circuit protection, making it an ideal general-purpose power supply for your workbench.

By JOHN CLARKE & LEO SIMPSON

Sooner or later, every electronics enthusiast needs a DC power supply. They used to get by with a variable supply giving up to 15V or so at around 500 milliamps but today's circuits using op amps, memory and logic devices need a lot more than that. For op amps you need balanced positive and negative supplies of ±15V while some memory chips such as EPROMs need ±5V.

The problem with designing a power supply is that it is easy to get carried away with fancy features that are seldom used. The end result is an expensive supply that no one can afford. This supply has good performance and features while keeping the cost within bounds.

What are the big cost items in a power supply? That was the question we asked ourselves as we set out to design this supply. The big cost items are the transformer, meter, case, filter capacitors and printed circuit board. We could not eliminate any of these components in a self-contained power supply so we selected them very carefully to optimise the performance versus price ratio.

For example, we selected a transformer with a centre-tapped 30V winding rated at one amp. This was much cheaper than a centre-tapped 44V 1.5A transformer that we would have selected as first choice if price was not so important. But we had to admit that the times when enthusiasts want high currents are fairly rare.

By picking the smaller transformer, we greatly cut down the power dissipation in the circuit and thereby reduced the heatsinking requirements, the size of the case and the cost of the filter capacitors and regulators, all for

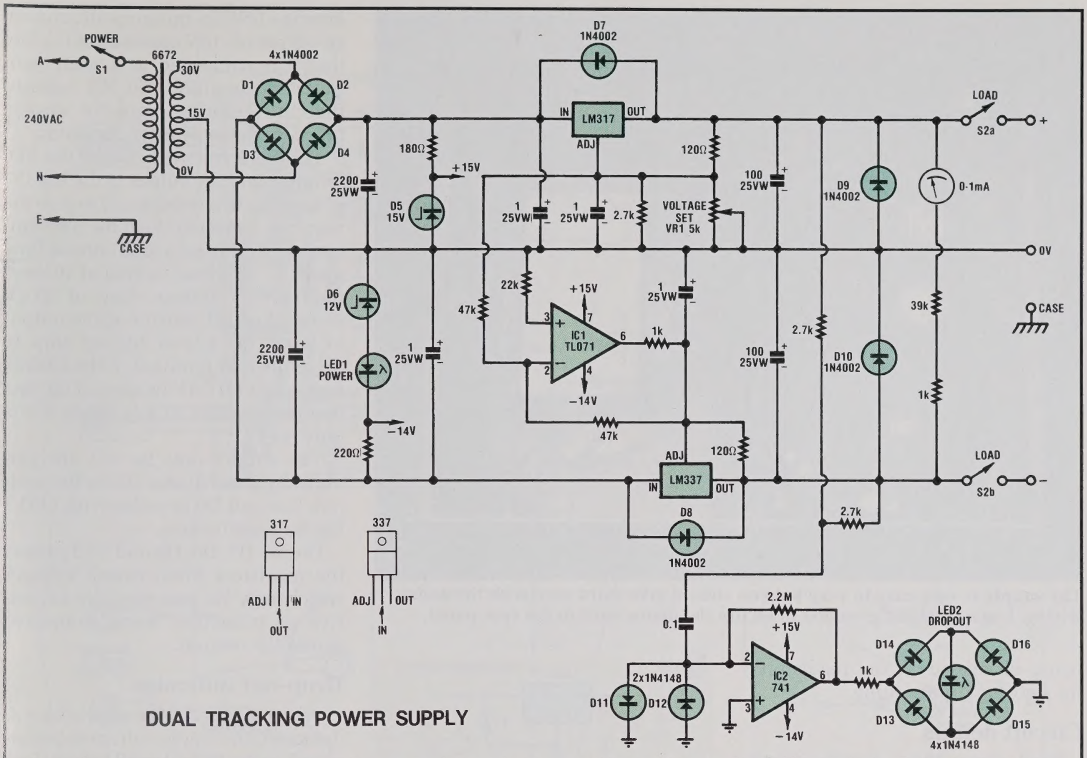

POWER
S1
A
240VAC
N
E
CASE
6672
30V
15V
0V
4x1N4002
D1
D2
D3
D4
2200
25VW
180Ω
+15V
D5
15V
D6
12V
2200
25VW
LED1
POWER
1
25VW
−14V
220Ω
D7
1N4002
IN
LM317
OUT
ADJ
1
25VW
1
25VW
2.7k
120Ω
VOLTAGE
SET
VR1 5k
100
25VW
D9
1N4002
0-1mA
LOAD
S2a
+
0V
CASE
22k
47k
+15V
IC1
TL071
−14V
1k
1
25VW
47k
39k
2.7k
100
25VW
D10
1N4002
1k
ADJ
120Ω
LM337
IN
OUT
D8
1N4002
2.7k
LOAD
S2b
−
317
ADJ
IN
OUT
337
ADJ
OUT
IN
2.2M
+15V
0.1
2x1N4148
D11
D12
IC2
741
−14V
1k
LED2
DROPOUT
D14
D16
D13
D15
4x1N4148
DUAL TRACKING POWER SUPPLY

Fig.1: the circuit uses a 30V 1A transformer to drive a bridge rectifier and two adjustable 3-terminal regulators. IC1 inverts the control voltage provided by VR1 to drive the LM337 regulator. IC2 monitors the output ripple to provide drop-out indication.

very little reduction in overall utility of the supply. We also saved money by using a smaller meter, smaller rectifier diodes and so on.

The end result is a compact power supply which will serve the needs of the vast majority of electronic enthusiasts and technicians.

The SILICON CHIP Dual Tracking Power Supply has tracking positive and negative DC outputs adjustable from ±1.2V to about ±18.5V. Both supply rails are protected against short circuits and voltages generated by external loads.

The maximum load current is 1.7A between ±3V to ±10V. When the supply stops regulating, a LED indicator lights.

You can use the power supply in the conventional way to provide balanced positive and negative rails, or you can take the output from between the positive and negative output terminals and thereby get more than 36V DC output. The circuit is fully floating (ie, not tied to mains earth) and so the output can be referenced to earth via the positive, negative or 0V rail.

What will it do?

Fig.2 shows the maximum output current available for voltage settings between ±1.2V and ±18V DC with the positive and negative rails loaded. Up to 1.7 amps is available for settings between ±3V and ±10V. Above 10V the available current reduces, to 200 milliamps at ±18V.

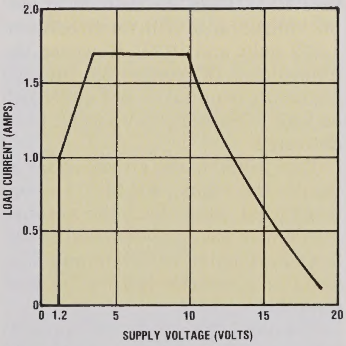
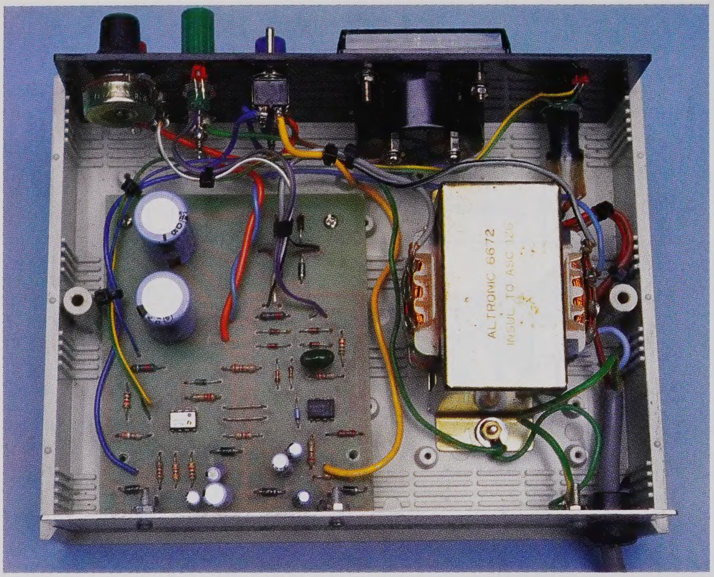


Fig.2: this graph plots the maximum output current for voltage settings between ±1.2V and ±18V.

Remember that this performance applies with both the positive and negative rails loaded, so that by taking the output between the positive and negative rails, you get up to 1.7 amps at 20V and up to 200 milliamps at 36V.

Line regulation is within ±5mV of a given output voltage setting for mains input variation between 220VAC and 260VAC. Load regulation at 1.7 amps is within 100mV at a setting of 9V; ie, close to 1%. Ripple output (ie, 100Hz hum and noise superimposed on the DC rails) is less than 1mV peak-to-peak for load currents up to one amp. These are excellent figures.

Note that the actual maximum available current from the power supply will depend on the temperature of the heatsink and the amount of power



The supply is very easy to wire but you should take extra care with the mains wiring. Use a cordgrip grommet to secure the mains cord to the rear panel.

being dissipated in the regulator(s) for a given output setting.

Circuit details

Fig.1 shows the complete circuit. As already noted, it is based on a 30V centre-tapped 1A power transformer, Arlec 6672A or equivalent. Diodes D1-D4 are connected as a bridge rectifier which, combined with the two 2200µF filter capacitors, give plus and minus DC rails of about 21V.

These unregulated DC rails are fed to LM317 and LM337 3-terminal regulators to provide the adjustable plus and minus supply outputs respectively. We'll briefly explain how these regulators work before going on with the rest of the circuit description.

The regulators are designed to give 1.25V between their output and adjust terminals. With this in mind, and the fact that the current flowing out of their ADJ (stands for ADJust) terminal is negligible, it is easy to design a variable regulated supply. The circuit of Fig.3 demonstrates their operating principle.

Two resistors are used to set the output voltage in the circuit of Fig.3. R1 is fixed while R2 is variable. Since the voltage between the OUT and ADJ terminals is fixed at 1.25V, the current through R1 and R2 is also fixed. This gives a simple formula for the output voltage as follows:

$$Vout = 1.25V(1 + R2/R1)$$

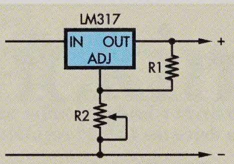


Fig.3: operating principle of the LM317 3-terminal regulator. R1 and R2 set the output voltage.

In our circuit R1 is 120Ω while R2 is made up of a 2.7kΩ resistor in parallel with VR1, a 5kΩ potentiometer. The maximum effective value of R2 is thus 1.75kΩ and the theoretical output voltage range is therefore between 1.25V volts and 19.5V. However, the unregulated DC voltage fed into the regulators is normally not quite high enough to enable 19.5V output to be delivered.

That explains the circuit as far as the positive regulator (LM317) is concerned but what about the negative regulator. It has an operational amplifier connected to its ADJ terminal instead of a variable resistor. So how does this work?

The idea of the op amp is to provide a mirror of the voltage at the ADJ terminal of the positive regulator. So if the ADJ voltage at the positive regulator is +10V, the op amp will produce an output of -10V by virtue of the fact that it is connected as a unity gain inverting amplifier. So IC1 ensures that the negative regulator always tracks with the positive regulator.

The 120Ω resistor between the ADJ terminal and the output of the LM337 is there for two reasons: (1) to give the required minimum load for the regulator; and (2) to set a load current flow into IC1. This load current of 10.4mA impresses a voltage drop of 10.4V across the 1kΩ resistor at the output of IC1. This allows the op amp to drive the ADJ terminal of the LM337 regulator to -17.3V in spite of the fact that the negative supply rail to IC1 is only -14V.

The supply rails for IC1 are provided by zener diodes D5 for the positive line and D6 in series with LED 1 for the negative line.

Diodes D7, D8, D9 and D10 protect the regulators from reverse voltages which may be generated by capacitive or inductive loads connected across the outputs.

Drop-out indicator

When the regulators are working as designed, the ripple voltage superimposed on the DC rails will be very low. However, if the current drain is higher than the regulator can supply while still maintaining about 2V between its input and output terminals, the ripple voltage will suddenly become quite high. The output voltage will fall rapidly if even more current is called for and the ripple will go even higher.

When this condition is beginning to occur you may have no idea that it is happening. You need a visible indicator. Hence, we have designed a drop-out indicator using IC2.

IC2 is connected as an inverting amplifier with a gain of about 800. It monitors both the positive and negative regulators via 2.7kΩ resistors and a 0.1µF capacitor. Diodes D11 and D12 limit any noise or ripple signal level to a maximum of ±0.7V.

The amplified ripple at the output of IC2 is fed to a full-wave rectifier consisting of D13-D16 via a 1kΩ limiting resistor. This in turn drives light emitting diode LED 2. The LED begins to glow when the ripple at one of the regulator outputs becomes greater than about 4mV peak-to-peak. At about 19mV p-p ripple the LED is fully alight.

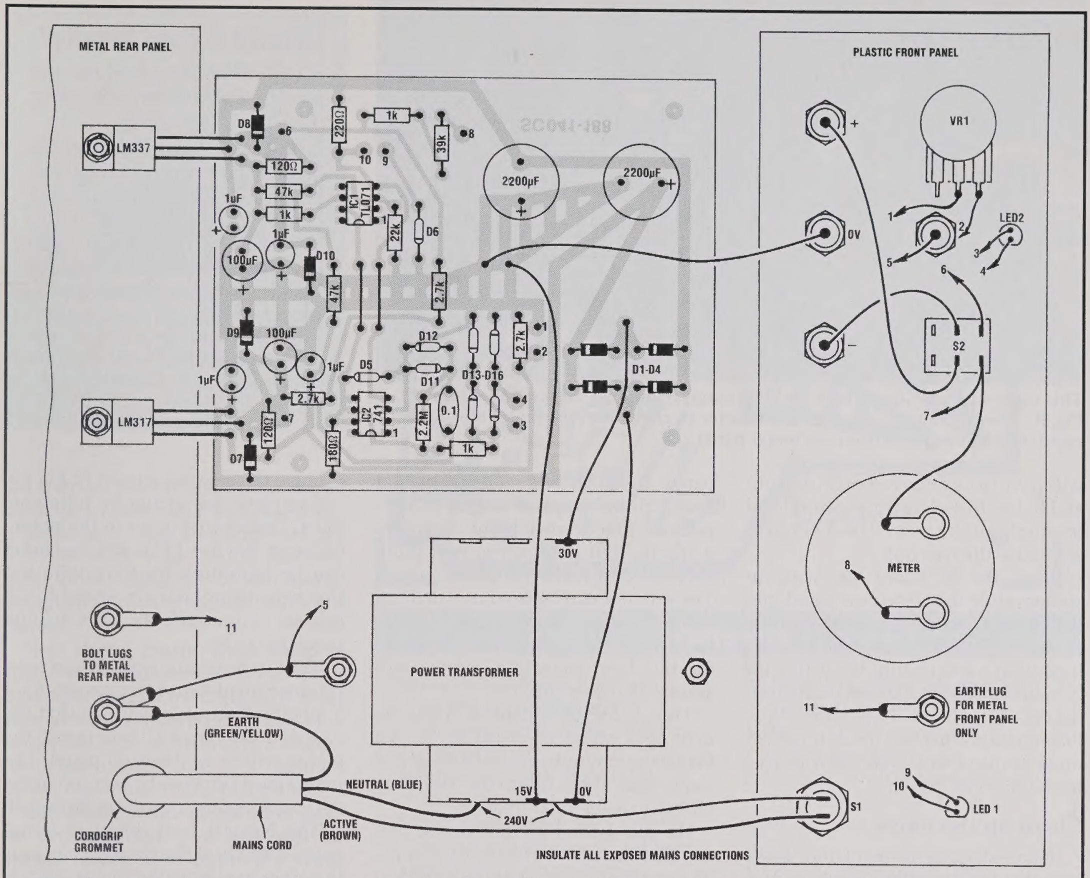

METAL REAR PANEL
PLASTIC FRONT PANEL
LM337
LM317
D8
D7
D9
D10
D5
D6
D11
D12
D13-D16
D1-D4
IC1 TL071
IC2 741
120Ω
47k
1k
1µF
100µF
220Ω
39k
22k
2.7k
2.2M
0.1
180Ω
2200µF
SC041-188
VR1
LED2
LED 1
S2
S1
METER
POWER TRANSFORMER
30V
15V
0V
240V
+
0V
−
BOLT LUGS TO METAL REAR PANEL
EARTH (GREEN/YELLOW)
NEUTRAL (BLUE)
ACTIVE (BROWN)
MAINS CORD
CORDGRIP GROMMET
EARTH LUG FOR METAL FRONT PANEL ONLY
INSULATE ALL EXPOSED MAINS CONNECTIONS
1
2
3
4
5
6
7
8
9
10
11

Fig.4: the wiring diagram for the power supply. Sleeve all exposed mains terminals, including the power switch terminals, with heatshrink tubing and note that the front panel must be earthed if it is made of metal (see text).

A 1mA meter monitors the output voltage via the 1kΩ and 39kΩ resistors. This gives it a full-scale reading of 20V.

Putting it together

The supply is housed in a standard plastic instrument case measuring 205 x 159 x 68mm. This case should have a plastic front panel and a metal rear panel.

All the circuitry with the exception of LEDs, switches and the pot, is accommodated on a PC board measuring 112 x 92mm (code SC041-188). Both regulators are bolted to the rear metal panel of the case for heatsinking.

You can start assembly by checking the copper pattern of the board for any breaks or shorts in the tracks. Compare it with the pattern published in this article.

With that done, you can install all the small parts on the PC board – see Fig.4. These include the resistors, diodes, links, small capacitors and the two op amps. Make sure that the ICs and diodes are correctly oriented before soldering them into place. Note that the two ICs face in the same direction.

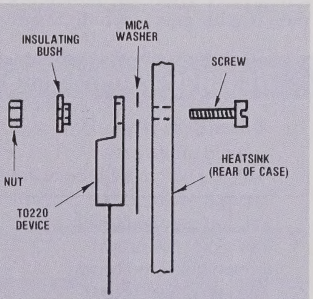
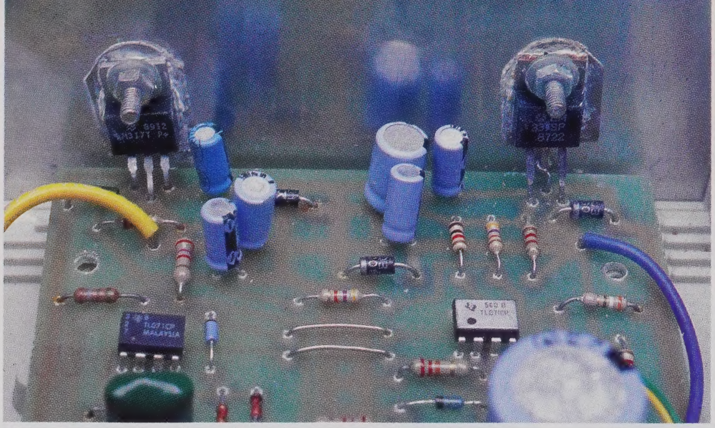

MICA WASHER
INSULATING BUSH
SCREW
NUT
HEATSINK (REAR OF CASE)
TO220 DEVICE

Fig.5: mounting details for the two 3-terminal regulators.

Next, install the two 2500µF capacitors and the two 3-terminal regulators. The regulators should be mounted so that their bodies are about 10mm clear of the board, to allow them to be easily bolted to the back panel of the case.

We recommend the use of PC pins for all external wiring from the board. They simplify connecting it up and give easy test points when checking voltages.

The completed PC board assembly is supported on four of the integral plastic standoffs on the base of the case and secured with self-tapping screws. The transformer must be mounted directly onto the base of the case. To do this, two of the standoffs



This close-up view shows how the 3-terminal regulators are mounted (see Fig.5). After mounting, use your multimeter to check that the metal tabs of the regulators are isolated from the metal panel.

What's A Dual Supply?

OK, so what's a dual tracking power supply and why would want one?

The word "dual" refers to the fact that this power supply has two supply rails, one positive and the other negative. The word "tracking" refers to the fact that when you adjust the positive supply, the negative supply automatically follows it so that it has the same absolute value. So if you set the positive output to +10V DC, the negative rail will be very close to -10V.

will have to be removed or drilled out and holes drilled for 3mm roundhead or countersunk screws. Use lockwashers under the two nuts.

When the PC board has been installed, slide the metal rear panel into the case and mark the mounting hole positions for the two regulators. The mounting holes should be drilled for 2.5mm screws. Fig.5 shows the mounting details for the two regulators. Note that a mica washer and insulating bush must be used to isolate each device from the metal panel.

Clean up the burrs

Before securing the regulators, make sure that the mounting holes are free of burrs. Lightly smear heatsink compound on the regulator heatsink surfaces and the mating areas on the metal panel. Then screw the two regulators to the panel as shown in Fig.5.

You should then switch your multimeter to a low Ohms range and use it to check that the metal tabs of the regulators are both isolated from the metal panel.

You can then work on the front panel. Kitset buyers can expect that they will be supplied with a screen-printed precut panel but if you're working from scratch you will probably have to make your own panel. The artwork can be used as a drilling template for the front panel. The meter is supplied with its own template for the four mounting screws and 46mm diameter cutout.

This latter hole can be made by drilling a series of small holes just inside the circumference of the marked circle and then filing the resulting cutout to a smooth circle.

Having drilled all the holes, you can affix the artwork to the front panel. The material covering the holes is then removed using a utility knife.

Now the front panel hardware can be mounted. In complete kits, a new scale should be supplied for the meter. This is easily fitted. Just unclip the meter bezel, undo two screws, remove the old panel and replace it with the new and then reassemble. Alternatively, you can remove the existing scale, erase the numbering and redo it with press-on lettering or you can use the artwork shown in Fig.6.

Complete the wiring by following Fig.4. Connecting wires to the potentiometer, the two LEDs and the meter can be light-duty hook-up wire but the remaining wiring should use heavier wire, such as 24 x 0.2mm insulated cable.

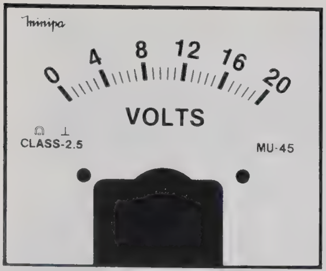
The 3-core mains cable should have its outer insulation layer removed for a length of about 100mm so that the Active lead (brown) can reach the mains switch on the front panel. The mains cord can then be secured to the rear panel using a cordgrip grommet.

The Neutral lead (blue) is terminated directly at the transformer, as is the other lead from the mains switch. **Both the mains termination on the transformer and the mains switch itself must be sleeved with heatshrink tubing to avoid the possibility of accidental shock.**

The mains Earth wire is terminated to one of two solder lugs which are securely bolted to the rear metal panel using a screw, nut and star washer. A lead also runs from the second solder lug to a solder lug secured by one of

Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	2.2MΩ	red red green brown	red red black yellow brown
☐	2	47kΩ	yellow violet orange brown	yellow violet black red brown
☐	1	39kΩ	orange white orange brown	orange white black red brown
☐	1	22kΩ	red red orange brown	red red black red brown
☐	3	2.7kΩ	red violet red brown	red violet black brown brown
☐	3	1kΩ	brown black red brown	brown black black brown brown
☐	1	220Ω	red red brown brown	red red black black brown
☐	1	180Ω	brown grey brown brown	brown grey black black brown
☐	2	120Ω	brown red brown brown	brown red black black brown



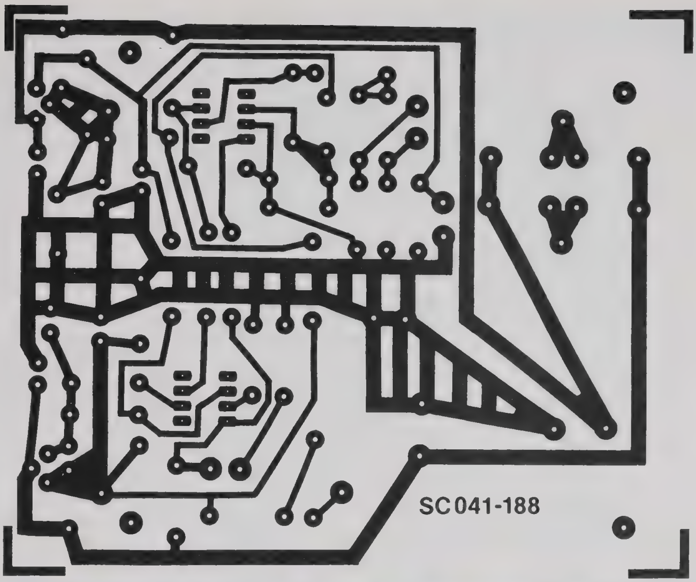


Fig.6: this full-size meter artwork should be used to replace the existing meter scale. The old artwork is removed by unclipping the meter bezel and undoing two small screws. Fig.7 (left) shows the full-size etching pattern for the PC board.

Parts List

- 1 plastic instrument case with plastic front panel and aluminium rear panel, 205 x 159 x 68mm
- 1 PC board, code SC041-188, 112 x 92mm
- 1 front panel label, 190 x 60mm
- 1 meter scale display, 52 x 43mm
- 1 6672 30V, 1A transformer
- 1 single-pole pushbutton mains switch (S1)
- 1 DPDT miniature toggle switch (S2a,S2b)
- 4 banana panel terminals (blue, white, red and green)
- 1 5kΩ potentiometer (VR1)
- 1 knob to suit
- 1 240V AC mains cord and plug
- 1 cordgrip grommet to suit mains cord
- 2 solder lugs
- 2 T0-220 insulating kits (mica washer and bush)
- 1 MU45 panel meter, 0-1mA movement

Semiconductors
- 1 LM317T positive adjustable 3-terminal regulator
- 1 LM337T negative adjustable 3-terminal regulator
- 1 TL071, LF351 op amp (IC1)
- 1 741 op amp (IC2)
- 8 1N4002, 1N4004 or equivalent 1A diodes (D1-D4, D7-D10)
- 6 1N914, 1N4148 diodes (D11-D16)
- 1 12V 1W zener diode (D6)
- 1 15V 1W zener diode (D5)
- 2 5mm red LEDs (LED1, LED2)

Capacitors
- 2 2200µF 25VW PC electrolytic
- 2 100µF 25VW PC electrolytic
- 4 1µF 25VW PC electrolytic
- 1 0.1µF metallised polyester

Resistors (5%, 0.25W)
- 1 2.2MΩ
- 2 47kΩ
- 1 39kΩ
- 1 22kΩ
- 3 2.7kΩ
- 3 1kΩ
- 1 220Ω
- 1 180Ω
- 2 120Ω

Miscellaneous
Solder, hook-up wire, heatshrink sleeving, screws, nuts, self-tapping screws, etc.

the transformer mounting screws, to earth the transformer frame. Use lock-washers and second locking nuts, so that the earth lugs cannot possibly come loose. An earth wire also goes to the green GND terminal on the front panel.

Note that a plastic front panel is specified for this design. If you use a case with a metal front panel, it must also be securely earthed by bolting a solder lug to it and running a mains-rated earth lead back to a separate solder lug bolted to the rear panel.

Important: if the aluminium panels are anodised, you will need to scrape away the anodising from around the earth lug holes to secure good electrical contact.

Finally, use several plastic cable ties to lace the mains wires together. This is an important safety measure as it prevents any wire that may come adrift from making accidental contact with the metalwork or vulnerable low-voltage circuitry.

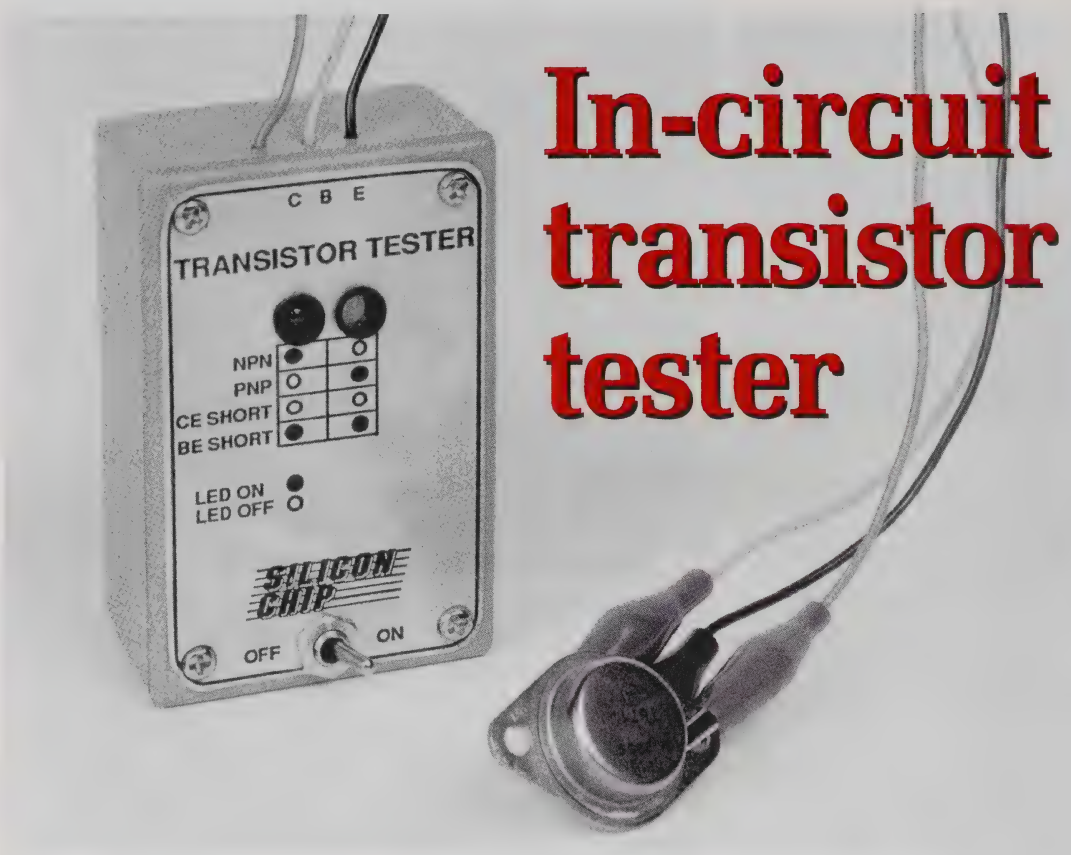
Testing

When all the wiring is complete you should carefully check your work against Fig.4. With that done, you can apply power and check the voltages. The unregulated voltages to the input of the two regulators should be about ±21V, while supplies to the two op amps should be +15V at pin 7 and -14V at pin 4.

Now check that the positive and negative supply rails can be varied over the range from below 1.5V to above 18V and that the two supplies track each other within ±100mV.

The dropout indicator can be checked for correct operation by connecting a 22Ω resistor across either the positive or negative supply. Now when the output voltage is wound up above 15V, the LED should light.

All that remains is to secure the lid of the case and your power supply is ready for work. **SC**



In-circuit transistor tester

Do you have a box full of unknown transistors or a transistor circuit that's not working properly? This simple tester will indicate whether a transistor is working or not and tell you whether it is an NPN or a PNP type.

IF YOU'VE BUILT a few projects, then the odds are that you'll have a fair collection of transistors in your junkbox. You will probably have a good range of types as well, ranging from small signal to high power devices.

After a while, it's easy to forget which ones are good and which are suspect. And if you've bought one of the semiconductor "grab bags" that some retailers offer, you'll undoubtedly have trouble determining which are NPN and which are PNP types – unless, of course, you have all the appropriate data books.

That's where this simple Transistor Tester comes in handy. It can test both small signal and power transistors and will indicate whether the device is an NPN or PNP type. Basically, it tells you whether a device is "go" or "no-go" and can indicate the nature of a fault – it cannot determine the lead configuration or tell you anything about the gain.

In addition, the project can be used to test transistors that are already in circuit. So if you have an AM radio, an amplifier or some other device that's not working, this project will prove invaluable for troubleshooting. You don't even have to bother pulling the transistors out of circuit to test them.

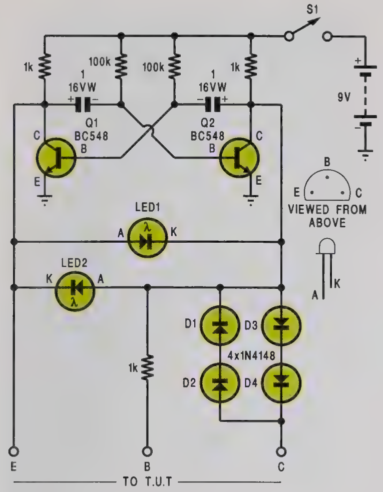
The test results are indicated by two LEDs mounted side-by-side on the front panel. If nothing is connected to the test leads, both LEDs flash rapidly. However, if a working device is connected, then one of the LEDs will go out, depending on whether the device is an NPN or a PNP type.

If the transistor is faulty, the result will depend on the nature of the fault. Both LEDs will flash if there is a base-emitter short, while both LEDs will go out if there is a short between collector and emitter.

A chart on the front panel shows what the results mean.

Circuit diagram

Let's now take a look at the circuit diagram – see Fig.1. It's based on tran-



IN-CIRCUIT TRANSISTOR TESTER

Fig.1: transistors Q1 & Q2 form a 5Hz multivibrator which alternately switches the collector & emitter terminals of the TUT high & low. If the device is good, one of the LEDs will alternately flash on & off.

sistors Q1 and Q2 which are wired to operate as a standard astable multivibrator. The frequency of oscillation is set to about 5Hz by the associated 100kΩ resistors and 1µF capacitors.

As a result, a 5Hz square-wave is produced at Q1's collector while a second 5Hz waveform of opposite phase appears at Q2's collector. Q1 drives the emitter of the transistor under test (TUT), while Q2 drives the base of the TUT via a 1kΩ resistor. The collector of the TUT is driven via diode array D1-D4.

Note that these are universal inputs; ie, both NPN and PNP devices connect to the same EBC test points without any need for switching.

The two LEDs are connected in reverse-parallel between the collectors of Q1 and Q2. Because the 5Hz output signals on the collectors of these two transistors are complementary, their voltage levels will be out-of-phase; ie, when one is high, the other is low. This causes both LEDs to flash alternately when power is applied, provided no TUT is connected.

NPN test transistor

Let's now see what happens when we connect a working NPN transistor as the TUT. There are two conditions to consider. The first is when Q1's collector is low and Q2's collector is high. In this case, the NPN TUT is biased on and so current flows through D3, D4 and the collector-emitter junction of the TUT. This means that there will be about 1.2V across D3 and D4, which is too low to keep LED 2 on.

Thus, LED 2 will go out when the test transistor is conducting. LED 1 will also be off during this time, since it will be reverse biased.

Now let's consider what happens when Q1's collector goes high and Q2's collector goes low. In this case, the TUT will be biased off and so LED 1 will be on. At the same time, LED 2 will be reverse biased and so will remain off.

Thus, if a working NPN transistor is used as the TUT, LED 1 will flash on and off at a 5Hz rate, while LED 2 will be off at all times.

PNP test transistor

For a working PNP transistor, the opposite occurs. When Q1's collector is low and Q2's collector is high, the TUT will be biased off and LED 2 will light. LED 1 will be reverse biased during this time and will be off.

When the collectors subsequently change state, the TUT will be biased on and current will flow through the transistor, this time via diodes D1 and D2. LED 2 will now be biased off, while LED 1 will remain off due to the low voltage across it. This voltage will be equal to the voltage across the two diodes plus the saturation voltage of the transistor (ie, a little over 1.2V).

Thus, when a good PNP device is used as the TUT, LED 1 goes out and LED 2 flashes.

Crook devices

What if you connect a TUT with a collector-emitter short? Regardless of whether it's an NPN or a PNP device, neither LED will light because the current will alternately flow through each of the series diode pair. This means that only about 1.2V will be developed across the LEDs, which is insufficient to turn them on.

If the base-emitter junction of the TUT is shorted, then the transistor will be unable to turn on and current will flow through the 1kΩ base resistor. Both LEDs will continue to flash since the voltage developed across this 1kΩ resistor is sufficient to allow them to operate.

Parts List

1 plastic case, 82 x 54 x 30mm
1 PC board, code 04109931, 51 x 37mm
1 self-adhesive front panel label, 49 x 79mm
1 SPDT toggle switch (S1)
1 9V battery
1 9V battery clip lead
2 LED bezels
1 150mm length of black hook-up wire
1 150mm length of yellow hook-up wire
1 150mm length of blue hook-up wire
3 small hook clips

Semiconductors
2 BC548 NPN transistors (Q1,Q2)
2 5mm green LEDs (LED1,LED2)
4 1N4148, 1N914 diodes (D1-D4)

Capacitors
2 1µF 16VW PC electrolytic

Resistors (0.25W, 1%)
2 100kΩ
3 1kΩ

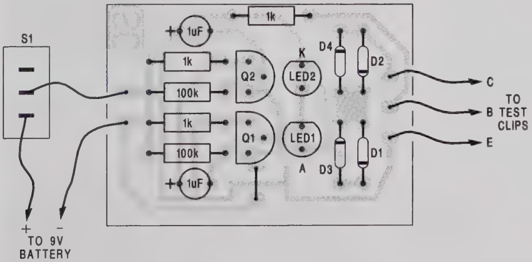
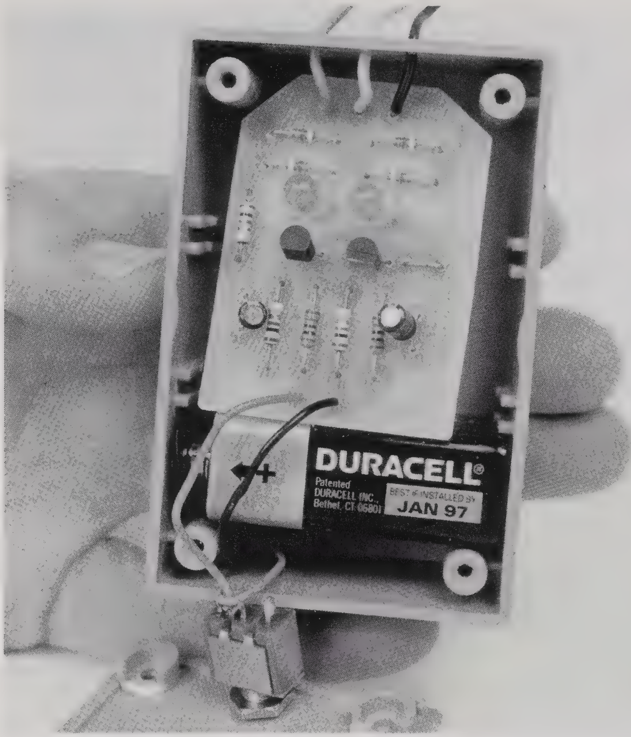


Fig.2: install the parts on the PC board as shown here. The LEDs are mounted about 15mm proud of the board & clip into two bezels on the front panel.



Make sure that all polarised parts are correctly oriented & note particularly that D1 & D2 face in the opposite direction to D3 & D4. The battery clip must be modified slightly to allow the battery assembly to fit inside the case – see text.

Power for the circuit is derived from a 9V battery.

Construction

Since there are only a few devices in the In-Circuit Transistor Tester, the construction is a breeze. All the components are installed on a single PC board measuring 51 x 37mm and coded 04109931.

Fig.2 shows where the parts go on the PC board. You can mount the parts in any order but make sure that the diodes, LEDs, transistors and electrolytic capacitors are the right way around. The two LEDs should be mounted so that their tops are about 15mm above the surface of the board, so that they later protrude through two bezels mounted on the front panel.

You can easily identify the LED leads since the anode lead will be the longer of the two.

The board can now be mounted inside a small plastic utility case. First, attach the adhesive label to the lid, then use it as a template to drill out the holes for the LED bezels and the on/off switch. In each case, it's best to drill a small pilot hole first and then carefully ream the hole out to the correct size. Three small holes are also drilled in one end of the case to take the flying Base, Emitter and Collector leads for the TUT.

This done, the on/off switch and LED bezels can be mounted and the wiring to the PC board completed. Use different colours for the test leads and feed them through the holes in the end of the case before making the connections to the PC board. The PC board is held in position by clipping the two LEDs into the bezels.

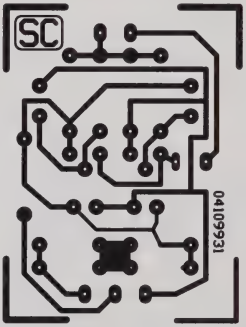


Fig.3: this is the full-size etching pattern for the PC board.

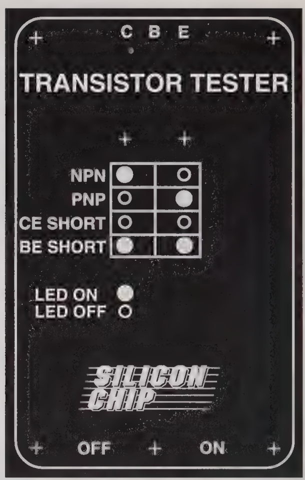


Fig.4: this full-size artwork can be used as a drilling template for the front panel.

The battery clip will have to be modified to allow the battery assembly to fit inside the case. This involves removing the plastic cover from the clip and soldering the leads onto the sides of the clip eyelets.

Finally, the three test leads must be fitted with hook-type test clips or alligator clips. Alligator clips were fitted to the prototype but you will find that small hook clips are easier to use.

As soon as you switch on, you should find that both LEDs flash at a rapid rate. To test the circuit, you'll need two working transistors – one an NPN device and the other a PNP. Check that only the lefthand LED flashes when you connect the NPN device and that the righthand LED flashes for the PNP device.

If both LEDs stay on or both go out and you are certain that the transistors are OK, check that the two LEDs are correctly oriented.

Finally, we should mention that the In-Circuit Transistor Tester does not work well with Darlington transistors. This is because they have a higher saturation voltage than normal transistors and so both LEDs will simply go dim for a working device. **SC**

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Diagnostic Cards

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Cat. 3128	**Diagnostic Card - ISA**	$64.50
Cat. 3422	**Diagnostic Card - PCI**	$89.50

Intelligent LAN Cable Testers

Hand-held and easy to operate, this intelligent continuity tester for LAN cables saves time on the job. It's intuitive interface keeps you from wasting time working through complex menus. You can easily diagnose RJ-45 cables against preset wiring schemes, verify cable continuity (open, short & mismatches), test for shielded & non-shielded cable types and review captured pin assignment & failure status.

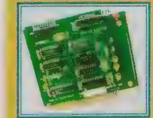
Cat .11518	**Intelligent LAN Cable Tester**	$216
Cat. 11519	**Network Tester with LCD Display**	$187
Also available:		
Cat. 11515	**Network Multi Modular Cable Tester Pro**	$160
Cat. 11516	**Network Cable Tester Enhanced**	$93

100Mbps Network Starter Kit

This kit has all the hardware components required to build a 100Mbps network for two PC's and includes a comprehensive installation manual. All software is part of Win 95/98/NT. The kit includes one 4 port 100Mbps Fast Ethernet hub, two 10/100Mbps PCI Fast Ethernet adapters, two 5 metre Cat. 5 network cables and software drivers for the adapters.

Cat. 11900	**100Mbps Network Starter Kit**	$216

Watch-Dog Timer



By adding a timing reset instruction to the outer loop of your program, this card will apply a hardware reset to the computer in the event of a lock up. Utility software included for DOS, Windows 3.1, Win 95, Windows NT, OS/2 & UNIX.

Cat.17044	**WatchDog Timer Card**	$142
Cat.17050	**WatchDog Timer II Card**	$328

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Parallel Port EPROM Programmer

An EPROM programmer that connects to LPT 1, 2 or 3 and has a 32 pin ZIF socket. It will program 16K to 8M bit EPROMs without adapters. Fully featured software accepts Binary-Intel/Extended Intel-Motorola S19/S28/S37 & Tektronics Hex formats. Optional adapters available.

Cat. No. 3159	**Parallel Port EPROM Programmer**	$375

RS232 Testers

We carry a large range of RS232 testers and wiring boxes to enable you to jumper or solder pins and check signal activity. A mini tester with 7 LED's allows you to monitor TD, RTS, DSR, CD, RD, CTS & DTR or monitor all pins with the 9 LED model. A loopback tester is also available.

Cat. MB380A	**RS232 Mini Wiring Box DB25 M/F**	$30
Cat. MB310	**RS232 Jumper Box DB25 M/F**	$12.30
Cat. MB550	**RS232 Break-Out Box V24 Tester DB25 M/M**	$37
Cat. MB340	**RS232 Mini Tester DB25 M/F**	$21.20
Cat. MB460	**RS232 Quick Tester DB25 M/F**	$23.50
Cat. MB455	**RS232 Loopback Tester DB25 M/F**	$20.80

Remote Power Control Kit via Internet

Control computers, swimming pool pumps, security lighting, heating, cooling etc. over an intranet or the internet. The kit includes a PCI PnP Digital I/O interface card, power control box and eight-in-one connecting cable. Fully functional demonstration software, with source code in VB and C++, is included as well video monitoring software.

Cat. 17064	**Remote Power Control Kit via Internet**	$545

FireWire PCI Interface Card

Connect your digital video camera to your PC. Our Firewire card allows IEEE 1394 FireWire devices (most digital camcorders available today) to connect to your PC at speeds up to 400Mbps. The card has three external and one internal 1394 connection ports to allow connections to hard drives, scanners, VCRs, HDTV, printers etc. Editing your videos is simplified with the bundled Ulead Video Studio DV SE software.

Cat. 2621	**FireWire to PCI Host Adapter**	$197

Windows Terminal

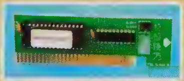
This windows based terminal is suitable for both NT Terminal Server & Citrix Metaframe as well as being configurable for Unix hosts. It supports Microsoft's RDP and Citrix ICA3 protocols. Ports provided include a DB25 parallel, two DB9 serial, two USB, VGA DB 15, PS/2 mouse & keyboard ports & audio in & out. It is used in conjunction with a standard monitor, keyboard & mouse.

Cat. 1214	**Windows Terminal**	$923

Serial and TCP/IP Ethernet LAN terminals.

Cat. 1133	**Serial Terminal 460Kbps**	$474
Cat. 1134	**TCP/IP Ethernet LAN Terminal**	$498

Hard Drive Recovery Card



This ISA 8-bit PnP recovery card allows recovery after FDISK/FORMAT/DELETE commands as well as virus attacks. It supports DOS, WIN3.x, WIN 95 and OS/2 operating systems and can run on 386/486/586 PC's. The card will support only one hard drive and you must partition the HD first. Once the partition has been made, the recovery card will automatically back up and all data will be recovered.

Cat. 3374	**Hard Drive Recovery Card**	$144

Hot-Swap IDE RAID Array

Avoid downtime delays when your hard drive fails! This unit enables the user to replace the hard disk while the PC is operating and it automatically resynchronizes itself to full operation. The RAID unit fits into two continuous 5.25" bays and includes a controller and two removable frames. The array accepts two EIDE, Ultra DMA 66/33 or PIO 4 hard drives. The controller provides RAID Level 1 disk mirroring. It can also be used as an on-line hard drive copier.

Cat. 2808	**HDD Hot Swap IDE RAID Disk Array**	$1175

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Cable & Wiring Tester

By LEON WILLIAMS

This Cable and Wiring Tester has a row of four LEDs to indicate the condition of a pair of wires: open circuit, short, reversed and good. A diode is hooked across the far end of the wire pair to assist the test which is done automatically as soon as you press the button.

O S R G
TEST
CABLE & WIRING
TESTER

Here's an easy to build and simple to use tester that will prove indispensable to anyone involved in the installation or maintenance of cables or wiring systems. Small enough to carry in a pocket, the tester employs four LEDs to speedily indicate the health of a pair of wires.

Tracing faults in cables, especially those in large buildings can be very difficult if you are working on your own. If you have a partner and some form of communication, you can use a multimeter set to measure resistance at your end while you get your partner to apply a short circuit and then remove it. With the short removed the meter should show an infinite resistance, and with the short applied a low resistance.

This is obviously difficult on your own, as you would have to travel between ends to place the short and remove it in between taking readings with the meter. Thankfully there's an easier way.

Diode testing

A technique that has been used for a long time to test cable pairs is to place a diode across the A and B wires of the pair at the remote end. When a meter is placed across the pair at the local end, a low resistance will be obtained with the meter leads connected one way and a very high (ideally infinite) resistance with the leads reversed. This happens because the diode only passes current in one direction; ie, when the anode is more positive than the cathode by about 0.7V.

A big advantage of the diode test is that fault conditions such as a short or open circuit can be diagnosed quickly. If a pair has a short circuit somewhere along its length, a low resistance will be seen when the meter is connected either way. Conversely an open circuit will show an infinite resistance with the meter connected either way.

The diode test will also show a reversed pair; ie, where the A and B wires get crossed along the way, as the low resistance/high resistance results will be opposite to those for a good pair. This goes to prove that the best ideas are sometimes the simplest. Fig.1 illustrates the four common pair combinations and the results obtained.

Easy to use

Carrying around an expensive multimeter, continuously turning it on and off and reversing the leads to test pairs is tedious. With the Cable and Wiring tester all you have to do is connect the two test leads to the pair under test and press the Test button. The tester will automatically test the pair and display the result on one of four LEDs.

The orange LED (O) will flash to indicate an open circuit and the yellow LED (S) will flash if the pair is short circuit. A pair that is reversed will cause the red LED (R) to flash, while a pair that is in good condition will cause the green LED (G) to flash. Of course you will need to connect the diode at the other end of the pair you are testing.

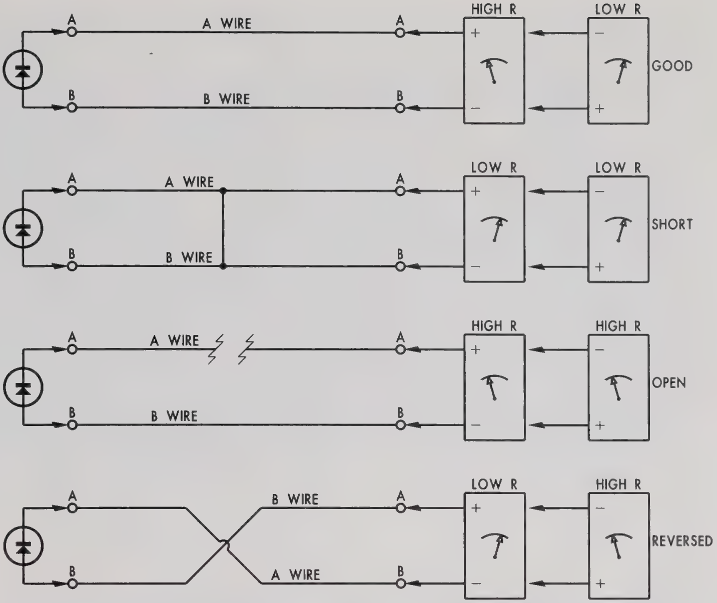

A
A WIRE
B
B WIRE
HIGH R
LOW R
GOOD
SHORT
OPEN
REVERSED
+
–

Fig.1: this series of the diagrams illustrates the method of testing a cable pair with a multimeter and a diode connected to the far end. The Cable and Wiring Tester runs through these tests automatically.

Circuit description

The Cable and Wiring tester works just like the manual diode testing shown in Fig.1 but it does it automatically in two phases before it displays the result. I will refer to these as phase 1 and phase 2. Fig.2 shows the circuit.

An oscillator is formed with IC2c, one section of a 40106 hex Schmitt trigger inverter, a 330kΩ resistor and a 0.22μF capacitor. It produces a square wave output with a frequency of about 20Hz. IC2d, a 100kΩ resistor and a 0.1μF capacitor form a delay circuit. The output at pin 10 of IC2d is a delayed and inverted replica of the output from IC2c.

The reason for the delay circuit is to separate the sample and display pulses from the unstable periods when the analog switches are swapping the polarity of the line. The oscillator controls the overall operation of the tester and when its output is low, it is in phase 1, and when its output is high, it is in phase 2.

In phase 1, analog switch IC1a connects wire A of the pair to pin 1 of IC2a, while IC1b connects wire B to ground. If the pair is good (ie, not reversed) and the diode is connected

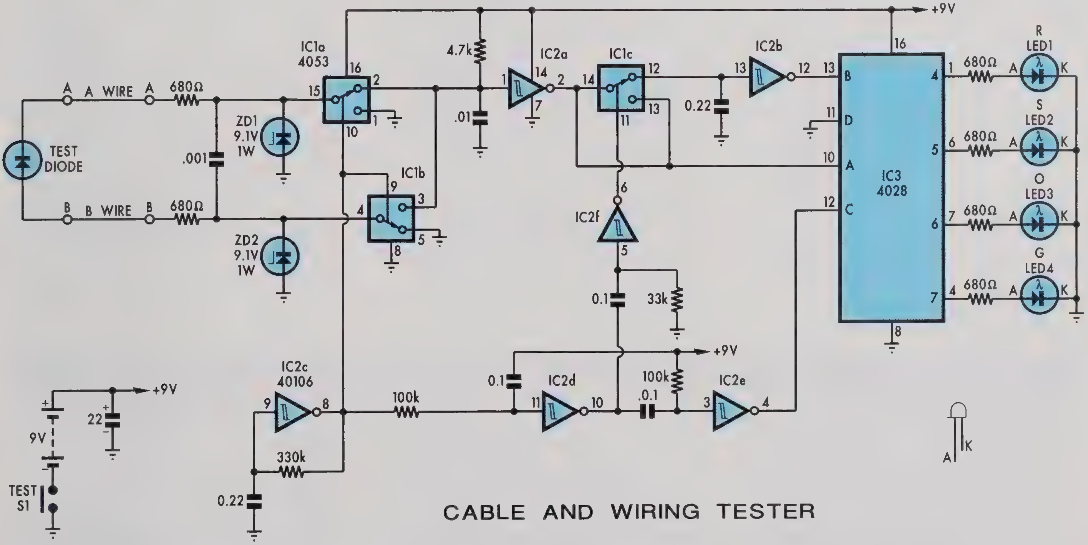

+9V
IC1a
4053
A WIRE
B WIRE
680Ω
TEST DIODE
.001
ZD1 9.1V 1W
ZD2 9.1V 1W
IC1b
4.7k
.01
IC2a
IC1c
0.22
IC2b
IC2f
0.1
33k
IC3
4028
R LED1
S LED2
O LED3
G LED4
680Ω
A
K
IC2c
40106
100k
IC2d
0.1
100k
.0.1
IC2e
330k
0.22
22
9V
TEST S1
CABLE AND WIRING TESTER

Fig.2: the Cable and Wiring Tester works by alternately applying DC voltage to a cable pair in one direction and then the other. The four possible conditions are indicated by the LEDs.

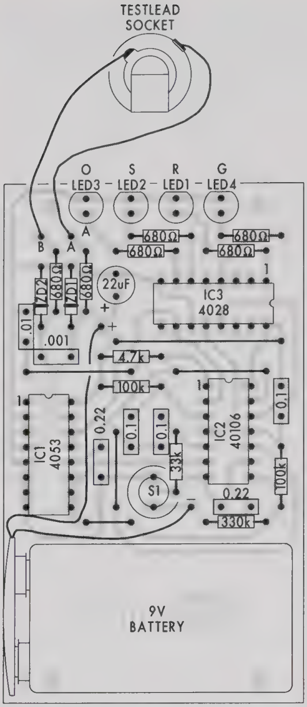
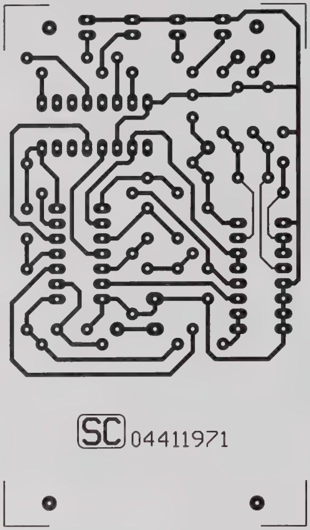


Fig.3 (left): the component layout for the PC board. Take care to ensure that all polarised parts are correctly orientated.

Fig.4 (below): this is the actual size artwork for the PC board.



with its cathode to wire A, no current will flow through this circuit and pin 1 of IC2a will be pulled high by the 4.7kΩ resistor. If the pair is short circuit or the diode is connected in reverse, current will flow and pin 1 of IC2a will be pulled to ground.

Assuming that all is well, pin 2 of IC2a will be low. IC2f, a 33kΩ resistor and a 0.1μF capacitor form a monostable which produces a narrow negative pulse when the output of IC2d goes high, which is only within phase 1. The negative pulse from IC2f closes analog switch IC1c and charges the 0.22μF "memory" capacitor connected to pin 12 of IC1c to the voltage present at pin 2 of IC2a.

When the pulse ends, the gate opens but the charge on the capacitor remains as the only discharge path is via the very high input impedance of inverter IC2b. The high output of IC2b is applied directly to the B input of the 4028 BCD-to-decimal decoder IC3.

During phase 2 the states of IC1a & IC1b are reversed and wire A is connected to ground while wire B is connected to pin 1 of IC2a. With a good pair, current will flow through the circuit and pin 1 of IC2a will be pulled to ground. The output (pin 2) of IC2a is connected directly to the A input of IC3. IC2e, a 0.1μF capacitor and a 100kΩ resistor form a monostable which produces a positive-going pulse when the output of IC2d goes low, which is only during phase 2.

This pulse is applied to the C input of IC3 and effectively becomes an enable input, as with this input low none of the LEDs can be selected. One of the LEDs will be turned on when the C input is high, depending on the state of the A and B inputs. Note that the D input is permanently connected to ground. With a good pair, both A and B will be high. The LEDs are only turned on for the period of the pulse from IC2e which has the added benefit that the current drain from the batteries is less than if a LED was on constantly.

In summary, the result of phase 1 is stored in the memory capacitor until the result of phase 2 is available, at which point they are both applied to the decoder and the respective LED is turned on.

Since high voltages could be present on the wires being tested, most likely in the form of static charges, each input is protected with a series 680Ω resistor and a 9.1V zener diode. A .001μF capacitor is also connected between the two inputs to shunt any RF signals that might otherwise be picked up by the wires under test.

The tester operates from a standard 9V battery which should last quite a long time. Note that the Test switch is also the power switch and is connected in the negative supply lead instead of the positive supply lead as is normal practice. This was done simply because it made the PC board layout easier.

Construction

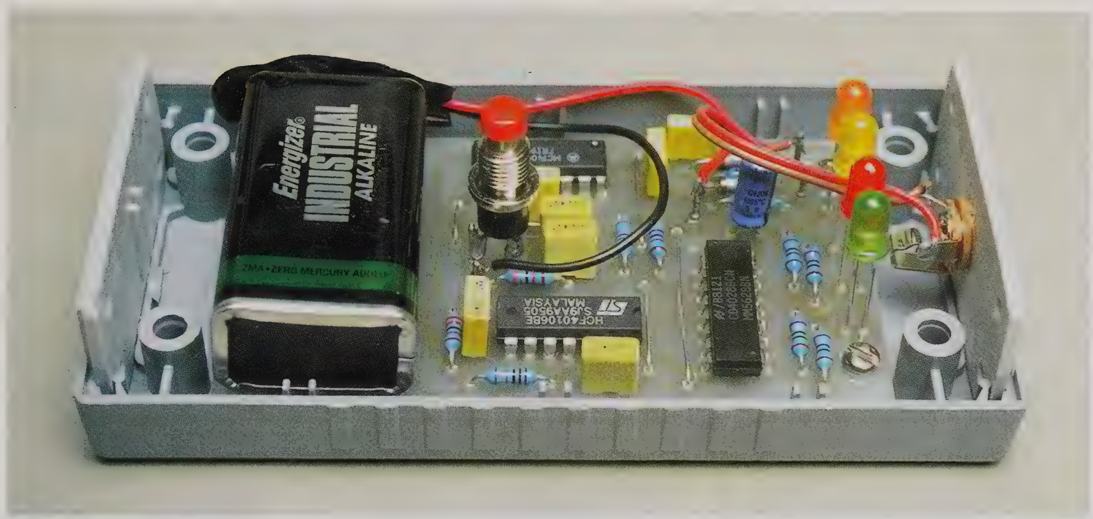
The Cable and Wiring Tester is mounted in a small plastic case with a row of four LEDs and a pushbutton on top. At one end is a 3.5mm jack socket to enable connection to a pair of wires. Pressing the button flashes one of the four LEDs depending in the test condition: Open (Orange); Short (Yellow); Reversed (Red); and Good (green).

All the components apart from the test socket are mounted on a single-sided PC board. Fig.3 shows the wiring diagram. Begin construction by soldering in the five tinned copper wire links, ensuring that they are straight and lay flat on the board. Follow this with the resistors, the zener diodes and the PC stakes.

Next, solder in the capacitors, remembering that the 22μF capacitor is polarised and must be inserted the right way. The integrated circuits can be installed next, ensuring that they are in the correct way. These are CMOS types and can be destroyed by static electricity, so earth yourself and take care not to handle them too much.

The LEDs are installed with the top of each LED 25mm above the PC board. They should protrude slightly from the lid of the case when it is fitted. Similarly, the pushbutton switch is installed in a vertical position by soldering its tags to two PC stakes. Again, the switch should be at the correct height with the case closed.

Install the PC board in the bottom case half with four self-tapping screws. If you find it won't sit properly, you can lightly file the edge of the board or cut out the small plastic tabs inside the edge of the case. Drill a hole in the centre of the top endplate and mount the 3.5mm test socket. Place the two



The four LEDs and the pushbutton switch are stood off the board so that they protrude through the lid of the case.

end plates in the slots on the bottom half of the case. The bottom half has four holes for the case mounting screws while the top half has threaded brass inserts.

Solder two wires from the socket to the PC stakes on the PC board. Now solder in the battery clip and trim the length of the wires so that they sit neatly with the battery positioned as shown in the photographs. You may find it necessary to cut off some of the plastic tabs on the inside of the top half to clear the battery clip when the two halves are screwed together. Drill the four holes for the LEDs and for the test switch in the top half of the case. The positions for these can be quite easily found by firstly making measurements with a ruler and then marking with a pencil before drilling.

The test lead is made from a short length of figure-8 cable. The type used in the prototype was coloured red and black. I soldered the red A wire to the centre pin of the 3.5mm plug and the

Parts List

1 PC board, code 04411971, 51 x 88mm
1 plastic case, 120 x 60 x 30mm
1 3.5mm mono phono socket
1 3.5mm mono phono plug
2 small black alligator clips
2 small red alligator clips
1 normally open pushbutton switch
6 PC stakes
1 9 volt battery clip
4 No. 4 x 6mm self-tapper screws

Semiconductors
1 4053 triple analog selector (IC1)
1 40106 or 74C14 hex Schmitt trigger (IC2)
1 4028 BCD-to-decimal decoder (IC3)
2 9.1V 1W zener diodes (ZD1,ZD2)
1 1N4004 diode (remote test diode)

1 5mm red LED (LED1)
1 5mm yellow LED (LED2)
1 5mm orange LED (LED3)
1 5mm green LED (LED4)

Capacitors
1 22µF 16VW electrolytic
2 0.22µF MKT polyester
3 0.1µF MKT polyester
1 .01µF MKT polyester
1 .001µF MKT polyester

Resistors (0.25W, 1%)
1 330kΩ
2 100kΩ
1 33kΩ
1 4.7kΩ
6 680Ω

Miscellaneous
Tinned copper wire, hookup wire, figure-8 cable, small piece of scrap stripboard, heatshrink tubing

Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	330kΩ	orange orange yellow brown	orange orange black orange brown
☐	2	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	33kΩ	orange orange orange brown	orange orange black red brown
☐	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	6	680Ω	blue grey brown brown	blue grey black black brown

gether. Now clip the tester leads to the diode leads, with the red A wire clips connected together and the black B wire clips connected together. Press the Test button and verify that the "G" LED flashes.

Now reverse the connection to the diode leads, press the Test button and check that the "R" LED flashes. Once you are happy with the testing, screw the case together with the four screws supplied, checking that the drilled holes line up with the LEDs and switch without placing stress on them.

Using the tester

The basic operation of the tester should be quite apparent. Simply connect the diode to the remote end with the red clip connected to the A wire, the tester to the local end with the red clip connected to the A wire, press the Test button and monitor the LEDs.

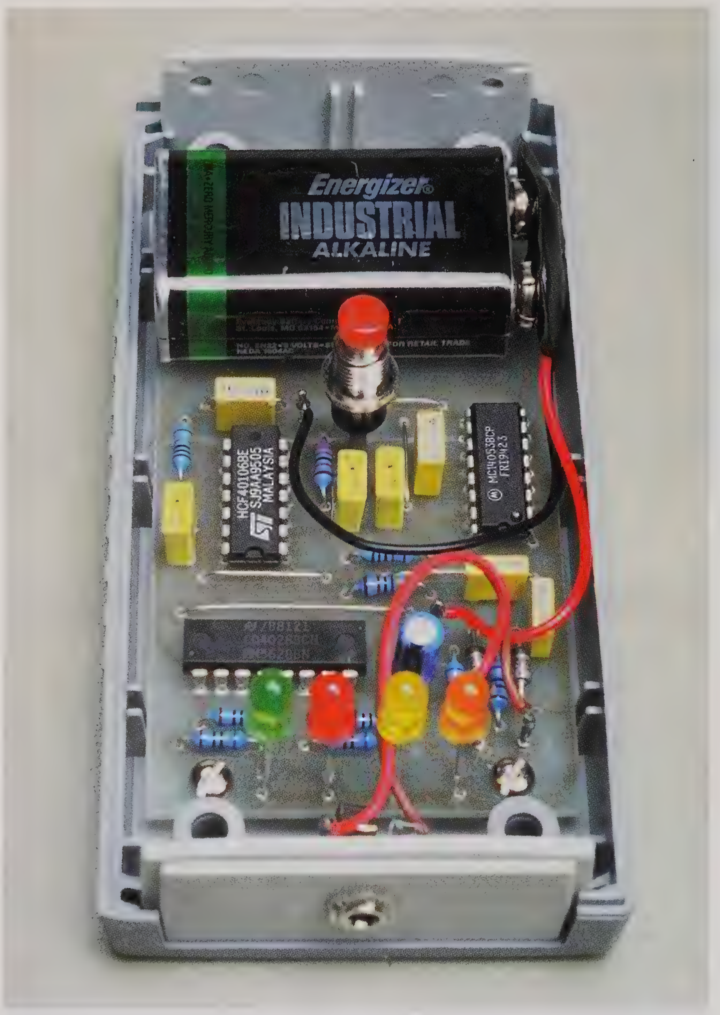
Multiple wire cables

So far this article has referred to just testing a pair of wires, such as those in a telephone cable or Local Area Network (LAN) cabling. However, the tester can be used to test cables with multiple wires even if they are not paired.

The simplest way is to select one of the wires as a common A wire and then progress through the other wires as a second B wire. If you are working on cable that has, for example three pairs, you might construct a multiple diode lead with three diodes and six leads so that you could check all the pairs at one time.

Some cabling systems use a special socket to terminate a multiple pair cable. An example of this is an RJ45 socket used in modern building cabling where four pairs provide computer and telephone connections at one socket. A plug could be adapted to hold four diodes and plugged into the remote socket while the tester could be plugged into a mating socket at the local end.

A switch would need to be incorporated in the tester leads to select the pair to be tested. Finally the tester can be used as a general continuity tester to test diodes, speakers, audio/video cables, etc. The tester will indicate a short circuit with about 2kΩ or less placed across the test leads but this will vary from unit to unit and is dependent mainly on the characteristics of the ICs used. **SC**



Another view of the prototype Cable & Wiring Tester. Power comes from an internal 9V battery.

black B wire to the ground pin. To finish the lead, solder a red alligator clip to the red wire and a black alligator clip to the black wire.

The diode assembly can be made next. It simply comprises a diode soldered to a length of figure-8 cable as before. Its anode is soldered to the black wire and the cathode to the red wire. I used a scrap piece of strip board to give the assembly some mechanical strength and then covered it with heatshrink sleeving to prevent accidental shorting. The red alligator clip is soldered to the red wire and the black alligator clip to the black wire. Finally, fit a good 9V battery into the case.

Testing

With the assembly complete, press the test switch briefly and check that the "O" LED flashes at about 20Hz. If it does, you can proceed with the rest of the testing. If it doesn't work, have a good look at the assembly again and check it for construction errors.

Plug the test lead into the socket and connect the two alligator clips together. Press the Test button and check that the "S" LED flashes to indicate that the wires are shorted to-

DIY Remote Control Tester

Do you have problems with your infrared remote controls? Are their batteries dead or is it just that some of the buttons are not working? These and other questions involving remote controls can be readily answered with this handy tester.

By LEO SIMPSON

DATA
PRESS
INFRA-RED
REMOTE
CONTROL
TESTER
OATLEY
ELECTRONICS
(02)-95843563

Everyone loves their remote controls, don't they? Whether they are used to mute those irritating adverts on TV or to fast-forward through adverts on taped programs, they are a real boon. And of course, they are used on a multitude of other appliances these days so we are really lost and frustrated when they don't work.

It is at these times that remote controls are instantly converted from items of utmost convenience to items of extreme frustration. How do you test them? You can't see the infrared beam that they are supposed to emit so you don't know if they are functioning or not. Then again, they might be functioning as far as some of the buttons are concerned and others might be dead. How do you find out?

On TV sets and other appliances which have an "acknowledge" LED, it is easy. Each time you press a button on the TV's remote control, the "ac-

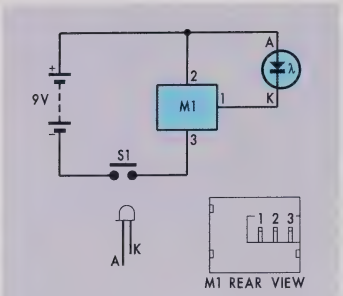


Fig.1: the circuit is based on an infrared detector module which drives the LED directly.

knowledge" LED flashes and you are instantly assured that all is well. But the "acknowledge" LED most likely doesn't work when other remote controls are pointed at it, so there's no help there. Some remotes also have a telltale red LED and thus they provide a good indication that they are working; most don't.

If you have a camcorder or video camera you can generally use it to check whether your remote is working. Just point it directly at the camera and you will see the telltale flashes in the viewfinder or monitor while a button is pressed. How so? Because most video cameras will respond to infrared light.

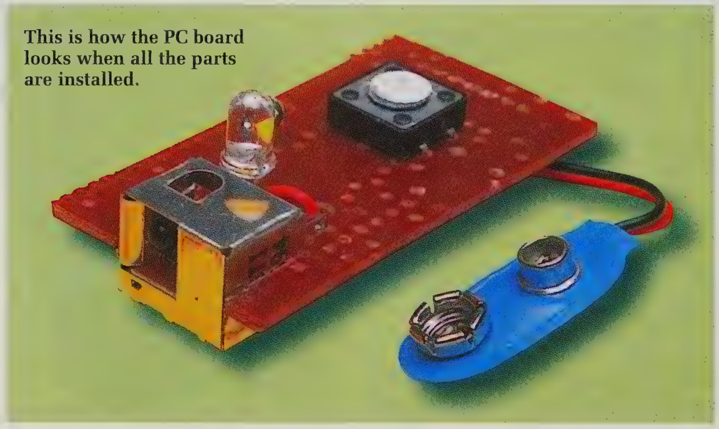
But while that is handy to know, it is not the most convenient setup if you are plagued with a pesky remote control that just does not want to behave and do what it's supposed to.

These thoughts were prompted by my recent bout of wrestling with a cantankerous remote control. It had been becoming increasingly unreliable over a period of a few months. The various users in the family responded by slapping it, pressing its buttons more fiercely and ultimately (shame) by saying unseemly words to it. None of these seemed to work as a cure.

Coincidentally, the remote control tester to be described arrived in the SILICON CHIP offices and I pounced on it. The idea is simple. It has a membrane key on the small case. You press it and then simultaneously press a button on your suspect remote. If it is working a LED on the remote tester flashes brightly, in time with the data modulated onto the infrared carrier. This is far more convenient than aiming the suspect remote at your TV.

The circuit of the remote control tester is shown in Fig.1. It consists simply of a 9V battery, a pushbutton switch, a LED and an infrared receiver module, M1. This infrared receiver module is contained in a compact tinplate case which houses a tiny PC board. This mounts an infrared detector diode, a surface mount preamplifier chip and number of other surface mount components. The module would normally be mounted behind a window in the front panel of a TV, VCR, CD player or whatever and would normally drive decoder circuitry.

In this case, we don't need any decoding. Instead, we want the tester to respond when any button on any IR remote control is pressed. That it does and it lights the LED on its front panel for as long as any button on the remote handpiece is pressed.



This is how the PC board looks when all the parts are installed.

The module has inbuilt current limiting so it can drive the red LED directly, without resistors or any other components being required.

Building it

The circuit of Fig.1 is so simple that you really don't need a PC board to build it but one is available as part of a kit from Oatley Electronics. The kit comprises a surplus PC board, a 9V battery snap connector, a high brightness red LED, the infrared receiver chip, a membrane switch and a small plastic case measuring 123 x 36 x 23mm.

The PC board measures 60 x 30mm and has been designed for a more complex circuit so there are a lot of vacant component positions. The photos show how the PC board is wired and how it sits in the case. Fig.2 shows the wiring layout.

Putting it together will only take a few minutes but you do have to be careful with the polarity of the infrared detector, the LED and of course, the battery wires. The infrared detector module straddles one end of the PC board and lugs on the tinplate case are soldered to adjacent copper pads on the PC board.

The positive battery wire passes through a hole in the PC board and is then wired directly to pin 2 on the module. The LED is wired directly across pins 1 & 2 on the module as well. The negative lead from the battery is wired to the membrane switch and then to pin 3 on the module.

When you have the unit complete, connect the battery and press the membrane switch. The LED should flash once. Then if you aim an infrared remote control at it and press a button, the LED should flash for as long as the buttons are pressed. Remember though, you also need to keep the membrane switch on the tester pressed.

Fixing remote controls

Well, once you have an infrared tester you will certainly be able to work out whether your remotes are working or not and whether some buttons are defective. But it is entirely another matter to fix them.

Let me tell you the story of the remote control that started this story. Well, the tester indicated that the remote was indeed malfunctioning and the TV was OK. But where was the

The PC board assembly sits at the top end of the case, with the battery occupying the other end. Take care to ensure correct battery polarity – the negative lead goes to the switch.

fault because one or two of the buttons would work some of the time?

The first step was to check the batteries, two AA cells being used in this case. They were around 1.4V each and although not fresh out of the carton, they certainly should have been good enough to run the circuit. Most remotes will run quite happily with cells that are down to 1.2V and some will work with a lot less.

Mind you, the batteries are often not the problem but corrosion of the battery terminals can be quite obvious when you take the trouble to look. This can be most easily cleaned off using a Scotch-Brite or similar scouring pad. Don't use steel wool as it is difficult, if not impossible, to ensure that there are no strands of it left to cause problems later.

While there was some corrosion on the battery terminals of this cantankerous remote, that was not the problem. It still would not work reliably. There was nothing for it but to pull it apart. This involved removing one screw on the back and then prising the case carefully apart. That revealed a long narrow PC board with just one surface-mount IC, the infrared LED and the contact patterns underneath each rubber button. There were no other components.

Older remotes can be expected to have quite a few components on the board and sometimes the fault can be a fractured component or a broken solder connection. This happens because remote controls are often dropped or sat upon.

Cleaning up

In the case of this remote the problem turned out to be blindingly obvious. Not only had quite a lot of food residue worked its way inside the case around the buttons and along the joins in the case but the PC board itself was wet! A sticky liquid was held between the rubber button sheet and the PC board. No doubt someone had spilt drink over it at some stage.

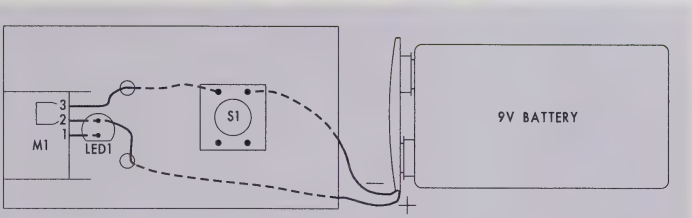


Fig.2: this is the wiring layout of the remote control tester. It uses a surplus PC board which fits into a small plastic case.

Drink residues, especially beer and cola, can be surprisingly hard to remove in this situation and since the PC board was largely bare in this case I decided to clean it up using kitchen detergent, thoroughly rinsed off with clean water. I was sorely tempted to dunk the whole PC board into the washing-up detergent but thought better of it. I also cleaned the rubber keyboard membrane but this job must be done carefully because it easy to inadvertently remove the resistive coating on the back of each button. It is this resistive coating which completes the circuit for each button and activates the remote control.

Having carefully rinsed off all the detergent from the PC board and the keyboard membrane, the drink residue appeared to be completely removed but it turned out not to be the whole cure. While it worked better when it was reassembled, it still would occasionally refuse to respond when some of the buttons were pressed. And even more irritating, sometimes none of the buttons would work! OK, I then cleaned the board and the button membrane again, this time using methylated spirits.

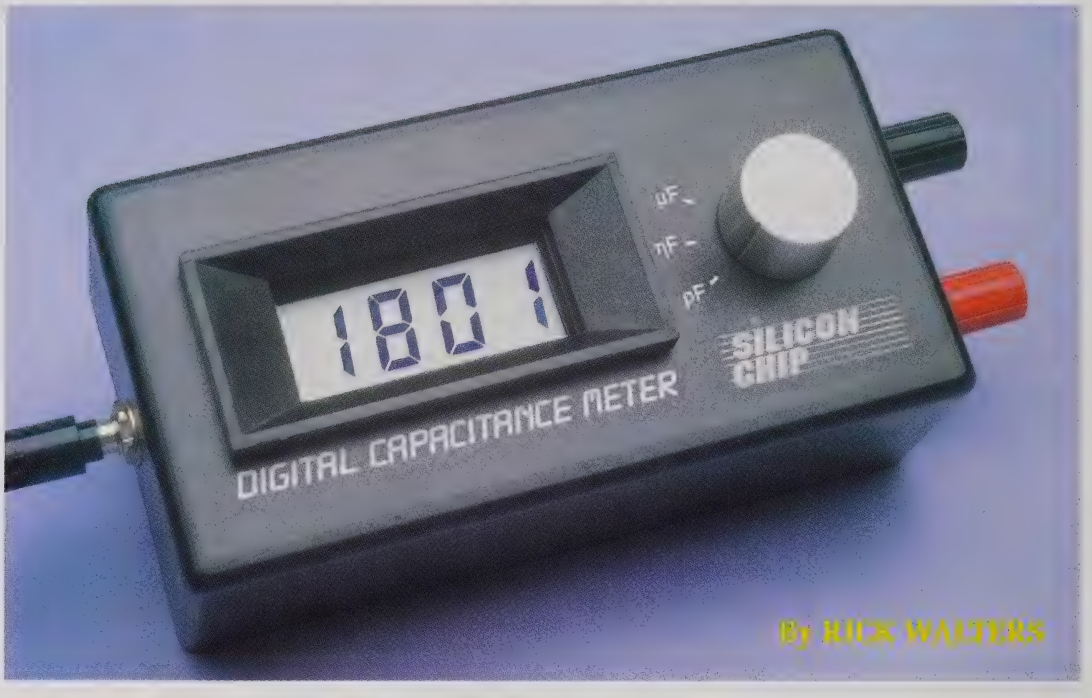
This turned out to be effective and the remote control then worked reliably – for a whole week! At the end of that time, the most used button just fell out! As you might expect, some more unseemly words were uttered.

There is no way that the missing button could be stuck back into place and since it was the one used to mute the commercials, the whole situation was rather frustrating. But wait! There is a solution. I will replace the missing button with a PC mount snap action switch. They're available from Jaycar, Dick Smith Electronics and Altronics, in various colours for a dollar or so.

Yes, I will have to ream out the button opening in the case but I'm going to fix this remote, come hell or high water! **SC**

Where To Buy The Kit

The complete kit for the remote control tester is available from Oatley Electronics. For further details, phone Oatley Electronics on (02) 9584 3563; or fax (02) 9584 3561; or go to their website www.oatleyelectronics.com.



By RICK WALTERS

Build A Digital Capacitance Meter

Got a junk box with a stack of capacitors with the values rubbed off? Maybe you are building a filter & need to match some capacitors closely. Or maybe you just can't read the capacitor labels. This neat little Capacitance Meter will soon let you check their values. It measures capacitors from a few picofarads up to 2μF.

Every multimeter will read resistance values but few will read capacitance or if they do, they don't read a wide enough range. This unit can be built in several forms. It can be a self-contained unit with its own digital display or it can be built as a capacitance adaptor to plug into your digital multimeter. And you can run it from batteries or an AC or DC plugpack.

Our preferred option is to build it as a self-contained instrument running from a DC plugpack. Batteries are OK but we prefer to do without them wherever possible. If you only use the item on infrequent occasions, the batteries always seem to be flat.

Our new Digital Capacitance Meter is a simple instrument with no-frills operation. It is housed in a small plastic utility box with an LCD panel meter and a 3-position switch labelled pF, nF and μF. There are two terminal posts for connection of the capacitor to be checked and no On/Off switch. To turn it on, you plug in your 12V plugpack.

The unit will measure capacitance values from just a few picofarads up to 2μF. Its accuracy depends on calibration but it should be within ±2%.

Theory of operation

The theory of operation of the capacitance meter is simple and is illustrated in Fig.1. We apply a square

Parts List

1 main PC board, code 04101991, 89 x 48mm
1 switch PC board, code 04101992, 44 x 30mm
1 plastic case, 130 x 68 x 41mm, Jaycar HB-6013 or equivalent
1 front panel label, 120 x 55mm
1 3-pole 4-position rotary switch
1 knob to suit switch, Jaycar HK-7020 or equivalent
1 power input socket, 2.1mm x 5.5mm, Jaycar PS-0522 or equivalent
1 red binding post
1 black binding post
2 3mm x 10mm countersunk head screws
4 3mm nut
2 3mm star washer
1 20kΩ multi-turn top adjust trimpot (VR1)
1 2kΩ multi-turn top adjust trimpot (VR2)
1 100kΩ vertical trimpot (VR3)

Semiconductors
1 74HC132 quad NAND Schmitt trigger (IC1)
1 74HC86 quad exclusive-OR gate (IC2)
1 TL071, FET-input op amp (IC3)
1 2N2222, 2N2222A NPN transistor (Q1)
1 78L05 5V 100mA regulator (REG1)
2 1N914 signal diodes (D1,D2)

Capacitors
4 100μF 25VW PC electrolytic
1 1μF 25VW PC electrolytic
1 0.1μF MKT polyester
2 .01μF MKT polyester
1 12pF NPO ceramic

Resistors (0.25W, 1%)
1 8.2MΩ
1 820kΩ
2 220kΩ
1 20kΩ
1 15kΩ
1 10kΩ
1 8.2kΩ
1 1.5kΩ

Panel Meter Option
1 panel meter, Jaycar QP5550 or equivalent
1 TL071 FET-input op amp (IC4)
1 0.1μF MKT polyester capacitor

Resistors (0.25W, 1%)
1 1.5MΩ
3 100kΩ
1 39kΩ
2 20kΩ
4 10kΩ
1 1kΩ
1 100kΩ vertical trimpot (VR4)

Battery Option
1 SPST toggle switch (S2)
1 9V battery (216)
1 battery clip to suit

Plugpack Option
1 12VDC or 9VAC plugpack
1 panel mounting socket to suit plugpack
1 78L05 5V 100mA regulator (REG2)
1 3.9V 400mW/500mW zener diode (ZD1)
1 1N4004 1A power diode (D3)
1 470μF 25VW PC electrolytic capacitor
1 2.2kΩ resistor (0.25W, 1%)

Miscellaneous
Hookup wire, machine screws & nuts, solder.

wave to one input of an exclusive-OR gate and feed the same square wave through a resistor to charge the capacitor we are measuring. The voltage on the capacitor is fed to the other input of the XOR gate. While the capacitor's voltage is below the input switching threshold the output of the gate will be high (+5V). An XOR gate's output is low when both inputs are the same (low or high) and high when they differ.

The larger the value of the capacitor the longer it will take to reach the threshold and consequently the higher the duty cycle of the output pulse waveform (ie, wide pulses). Putting it another way, if the capacitor is small, it won't take long for it to charge and so the resulting pulses will be very narrow. This pulse waveform is integrated (filtered) and fed to a voltmeter. The circuit time constants are arranged to make the voltage reading directly proportional to capacitance.

How it works

Of course, like all theory, the practical realisation is a lot more complicated. The circuit of the Capacitance Meter is shown in Fig.2 and you may find difficulty in seeing any resemblance between it and the simple circuit of Fig.1. Never fear; we will explain it all.

First, IC1a is a Schmitt trigger oscillator and it oscillates at a rate determined by the switched resistors and the .01μF capacitor. IC1a has an output frequency of 16kHz on the pF range, 160Hz on the nF range and 16Hz on the μF range. The (approximate) square wave output is buffered and inverted by gates IC2b, IC2c and IC2d which have their outputs wired in parallel. These outputs are fed directly to pins 9 and 12 of IC1 and through trimpot VR2 and the 15kΩ resistor to the capacitor we are measuring (CUT).

The XOR gate IC2a corresponds to the single XOR gate shown in Fig.1. Note that Q1, the transistor that discharges the capacitor at the end of each charge cycle, is a 2N2222. This has been specified instead of the more

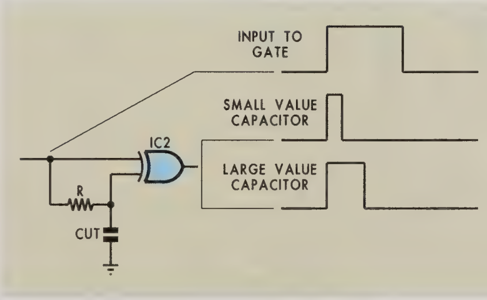


Fig.1: this is the principle of the Digital Capacitance Meter. A square wave is fed to an XOR gate and the time delay in charging the capacitor produces a pulse waveform with its duty cycle proportional to the capacitance.

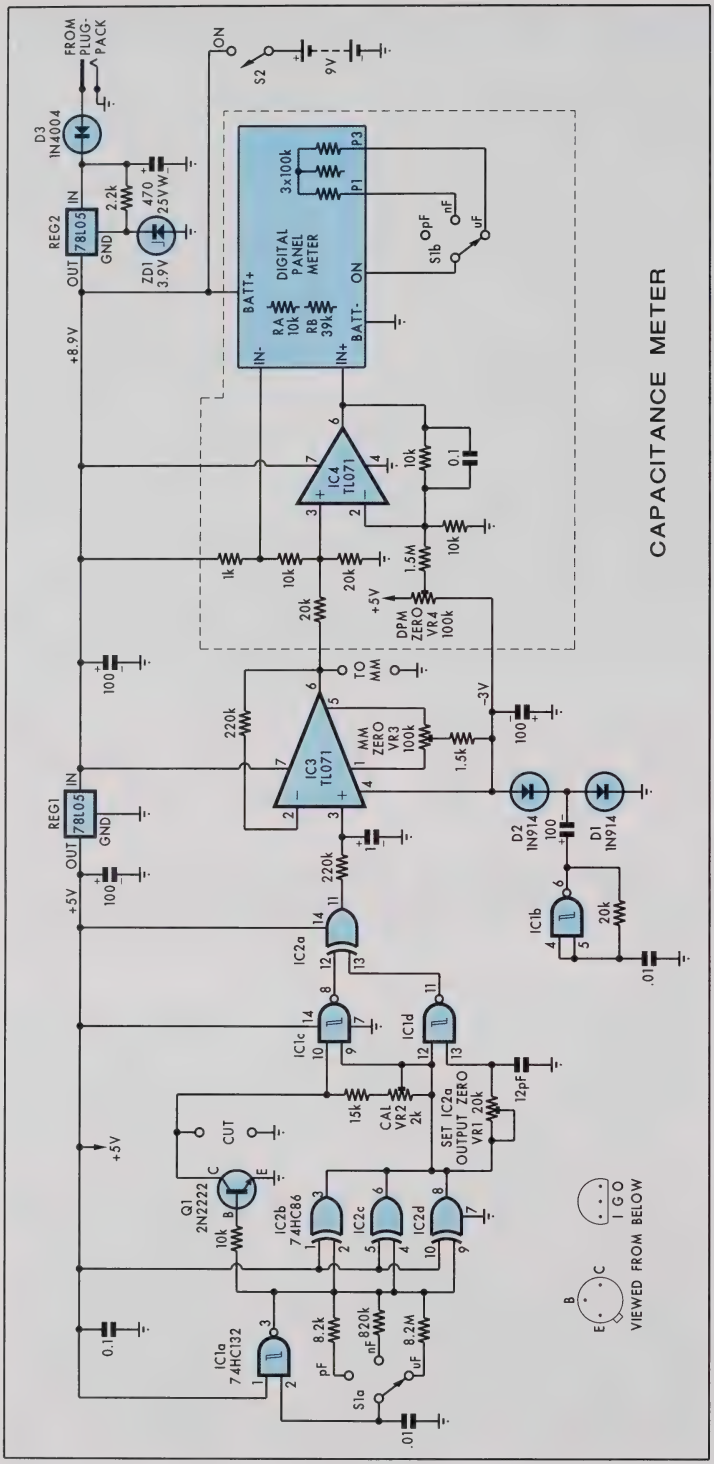

CAPACITANCE METER
FROM PLUG-PACK
D3 1N4004
REG2 78L05
IN
OUT
GND
2.2k
470 25VW
ZD1 3.9V
ON
S2
9V
+8.9V
DIGITAL PANEL METER
3x100k
P3
P1
BATT+
BATT-
IN-
IN+
RA 10k
RB 39k
S1b
pF
nF
uF
IC4 TL071
0.1
10k
1.5M
1k
20k
+5V
DPM ZERO VR4 100k
100
TO MM
220k
IC3 TL071
MM ZERO VR3 100k
1.5k
-3V
REG1 78L05
D2 1N914
D1 1N914
IC2a
IC1b
.01
IC1c
IC1d
12pF
15k
CAL VR2 2k
SET IC2a OUTPUT ZERO VR1 20k
CUT
Q1 2N2222
C
B
E
IC2b 74HC86
IC2c
IC2d
8.2k
820k
8.2M
IC1a 74HC132
S1a
I G O
VIEWED FROM BELOW

Fig.2: this circuit can be built as a capacitance adaptor for a digital multimeter or as a self-contained instrument with its own LCD panel meter. It can be powered from a 9V battery or a DC plugpack, in which case the circuit involving REG2 is required.

common varieties such as BC547 or BC337, in order to get sufficiently fast switching times.

We use two of the Schmitt NAND gates of IC1 (74HC132) as the inputs to IC2a and this has been done to ensure that these inputs make very fast transitions between low and high and vice versa. Without the Schmitt trigger inputs, the XOR gate circuit of Fig.1 tends to have an indeterminate performance and the pulse output can be irregular.

The "capacitor under test" (CUT) charges via VR2 and the 15kΩ resistor and eventually the voltage at the input of IC1c (pin 10) will reach its switching threshold and pin 8 will go low. The capacitor is then discharged by transistor Q1 which is driven from the output of oscillator IC1a. The cycle then repeats, with the capacitor being charged again. The waveforms of Fig.3 illustrate the circuit operation.

This output pulse from IC2a is integrated by a 220kΩ resistor and a 1µF capacitor to provide a DC potential to the pin 3 input of op amp IC3, which is connected as a voltage follower. Trimpot VR3 is used to set the output at pin 6 to zero when the input is zero. This "offset adjust" is most important as an offset as low as 1mV is equivalent to a reading of 1pF on the most sensitive range.

Since the output of IC3 must be able to swing to zero, IC3 needs a negative supply rail and this is provided by IC1b which is connected as a 10kHz oscillator. Its square wave output is rectified by diodes D1 & D2 in a diode pump circuit. The resulting DC supply is about -3V.

Stray capacitance

Even with no external capacitor connected, the stray capacitance on the PC boards and the interconnecting-wiring will have to charge and discharge. This stray capacitance will thus be seen by the rest of the circuit as a capacitor connected across the terminals. In effect, the stray capacitance will slightly slow the charging and discharging of the real capacitor under test.

To compensate for the stray capacitance, we've added a delay circuit to the pin 13 input of IC1d. The idea is to provide the same delay to IC1d as the stray capacitance causes to pin 10 of IC1c. Then both delays will cancel out. The delay circuit consists of a variable resistor (VR1) and a 12pF capacitor. VR1 can be adjusted so that with no external capacitor connected, the output of IC2a (pin 11) always stays low.

So far then we have described all the circuit you need if you plan to use your multimeter as the readout. The output of IC3 is can be fed directly to a digital multimeter and the reading in mV corresponds to the capacitance in pF, nF or µF. So if the reading is 0.471V and you are switched to the pF range, the capacitance is 471pF.

Digital panel meter

Unfortunately, we can't simply feed the output of IC3 to a digital panel meter to make the instrument self-contained. This is because currently available digital panel meters appear to take their reference from their 9V supply rail and so their input voltage needs to be offset with respect to the 0V line. That means that the panel meter usually needs a separate isolated 9V power supply which could be a big drawback.

Fortunately, John Clarke has figured out an elegant way to solve the problem.

As the negative input of the panel meter sits around 2.6-2.8V below the positive rail (say 6.3V for a 9V supply), we need an op amp to shift the output of IC3 from a 0-1.999V range to a 6.3-8.2999V range. IC4 does this for us.

The output of IC3 is attenuated by a factor of 4 by the two 20kΩ resistors and the 10kΩ resistor connected to pin 3 of IC4, while the gain of 2 is determined by the 10kΩ feedback resistors connected to pin 2. The 1.5MΩ resistor has a negligible effect.

Thus, the 0-1.999V variation at the output of IC3 is translated to a 1V swing at the input of the digital panel meter. Resistors R_A and R_B are chosen to be 10kΩ and 39kΩ respectively for the meter's attenuator, which gives it a full scale sensitivity of 1V for a display of 1999.

Trimpot VR4 sets the panel meter's readout to zero when the output of IC3 is zero. The decimal points on the display are all tied to the OFF connection through 100kΩ resistors. To illuminate a decimal point it is connected to the ON terminal by S1b, the second pole of the range switch.

Power supply

As already noted, the Capacitance Meter can be run from a 9V battery or from a DC or AC plugpack. If you plan to use a 9V battery, then you will have to fit an on/off switch instead of the plugpack socket. The 9V battery then feeds the panel meter, IC3 and IC4 directly and the 3-terminal 5V regulator REG1.

REG1 supplies CMOS gates IC1 and IC2. This is necessary to ensure that the meter's calibration does not vary with changing supply voltage.

If you plan to use a plugpack, more circuitry is required and this involves diode D3 and the additional 3-terminal regulator REG2.

Diode D3 ensures that a DC plugpack cannot cause any damage if it is connected with the wrong lead polarity. It then feeds REG2 which is jacked up by 3.9V zener diode ZD1 so that it delivers 8.9V to IC3, IC4 and the digital panel meter. REG2 also supplies REG1.

PC board assembly

The Digital Capacitance Meter uses two PC boards as well as the digital panel meter. The main PC board houses most of the circuitry while there is a smaller board for the range switch. Before starting assembly, check each PC board for defects such as shorted or broken copper tracks or undrilled holes. The diagram of Fig.4 shows the details of the two PC boards and all the interconnecting wiring.

You can begin by assembling the switch board which mounts just the 3-position switch and three resistors. Note that the specified switch is a 3-pole 4-position rotary type and it will have to be changed to give just three positions. This is done by removing the switch nut and washer, then prising up the flat washer which has a tongue on it. Move the tongue to the next anticlockwise hole and refit the washer and nut. It may sound complicated but once you are actually doing it, it will be straightforward. Make sure the switch provides three positions before you solder it to the board.

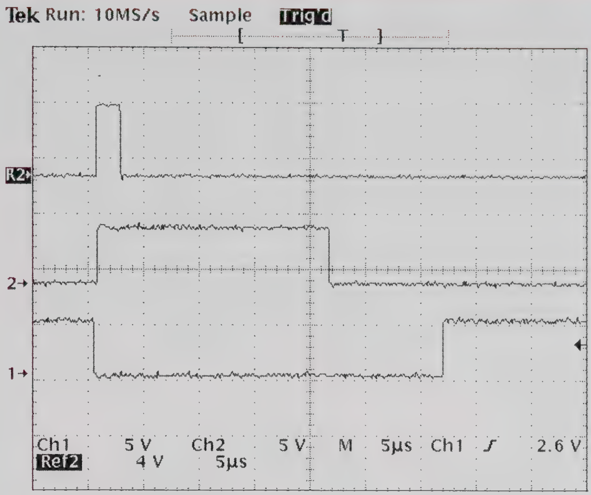
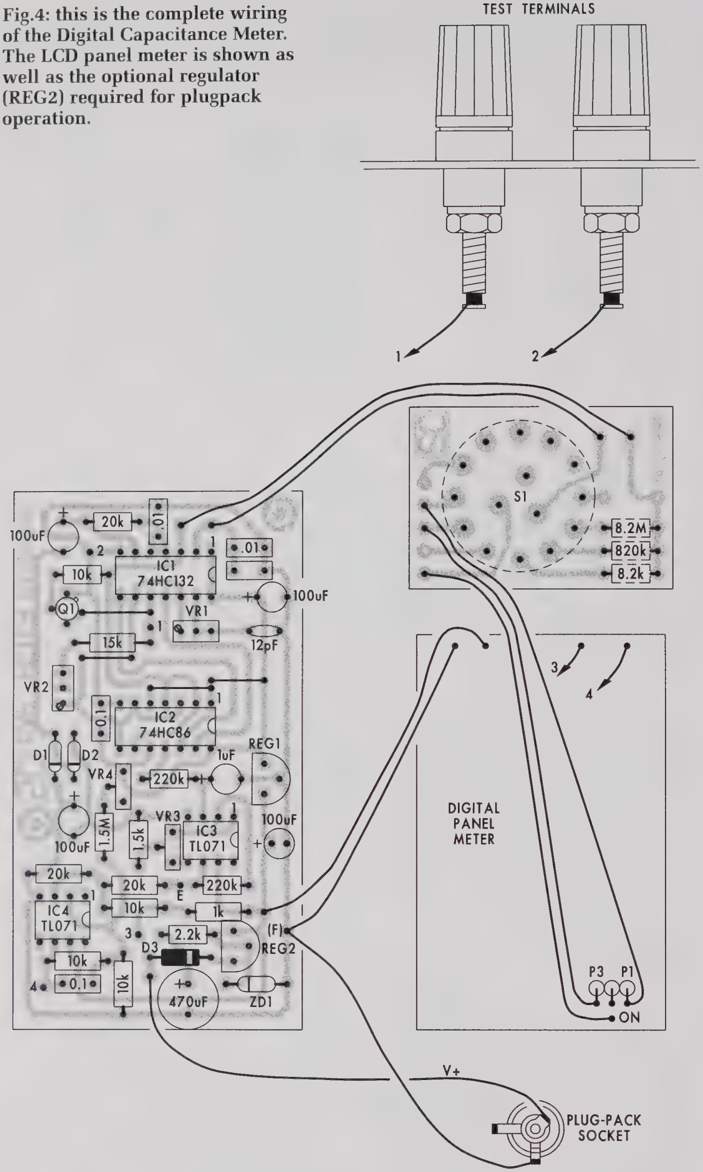
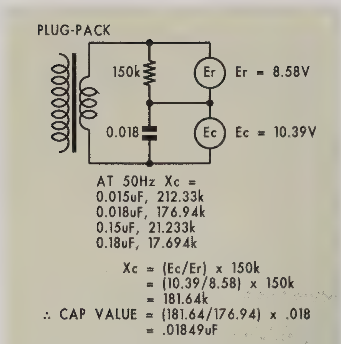

Tek Run: 10MS/s Sample Trig'd
T
R2
2
1
Ch1 5 V Ch2 5 V M 5µs Ch1 ∫ 2.6 V
Ref2 4 V 5µs

Fig.3: these waveforms show the operation of XOR gate IC2a. The bottom trace is the oscillator square wave while the top trace is the output with a small capacitor under test. The middle trace shows the output waveform for a larger capacitor. The output waveform is then integrated (filtered) to produce a DC voltage which is proportional to capacitance.

Fig.4: this is the complete wiring of the Digital Capacitance Meter. The LCD panel meter is shown as well as the optional regulator (REG2) required for plugpack operation.


TEST TERMINALS
1
2
3
4
S1
8.2M
820k
8.2k
DIGITAL PANEL METER
P3
P1
ON
100uF
20k
.01
.01
2
1
10k
IC1 74HC132
Q1
VR1
100uF
15k
12pF
VR2
0.1
IC2 74HC86
1
D1
D2
VR4
220k
1uF
REG1
100uF
1.5M
1.5k
VR3
IC3 TL071
100uF
20k
20k
220k
E
IC4 TL071
10k
1k
3
2.2k
(F)
REG2
D3
10k
4
0.1
10k
470uF
ZD1
V+
PLUG-PACK SOCKET


PLUG-PACK
150k
0.018
Er
Ec
Er = 8.58V
Ec = 10.39V

AT 50Hz Xc =
0.015uF, 212.33k
0.018uF, 176.94k
0.15uF, 21.233k
0.18uF, 17.694k

Xc = (Ec/Er) x 150k
= (10.39/8.58) x 150k
= 181.64k
∴ CAP VALUE = (181.64/176.94) x .018
= .01849uF

Fig.5: this diagram shows the connections and formulas to be used when calculating a capacitor's value for the calibration method. The digital multimeter used is assumed to have a typical accuracy of 2%.

Next, fit and solder the links, resistors and diodes into the main board, then mount the trimpots, capacitors, 3-terminal regulators and transistor. By the way, the 78L05 regulators look like ordinary plastic TO-92 transistors because they have the same encapsulation. They don't work like transistors though, so don't confuse them with the TO-18 metal-encapsulated 2N2222 transistor.

Finally, mount the op amps and lastly, the two CMOS ICs.

Once the two PC boards are assembled, it is time to work on the plastic case which needs the cutout for the LCD panel meter and the other holes drilled. The specified panel meter comes with a bezel surround so you don't need to be ultra-neat when making the cutout for it.

It is easier to drill all the holes in the plastic case and check that everything fits before wiring the units together. If you don't intend to use the LCD panel meter you may be able to use a slightly smaller case.

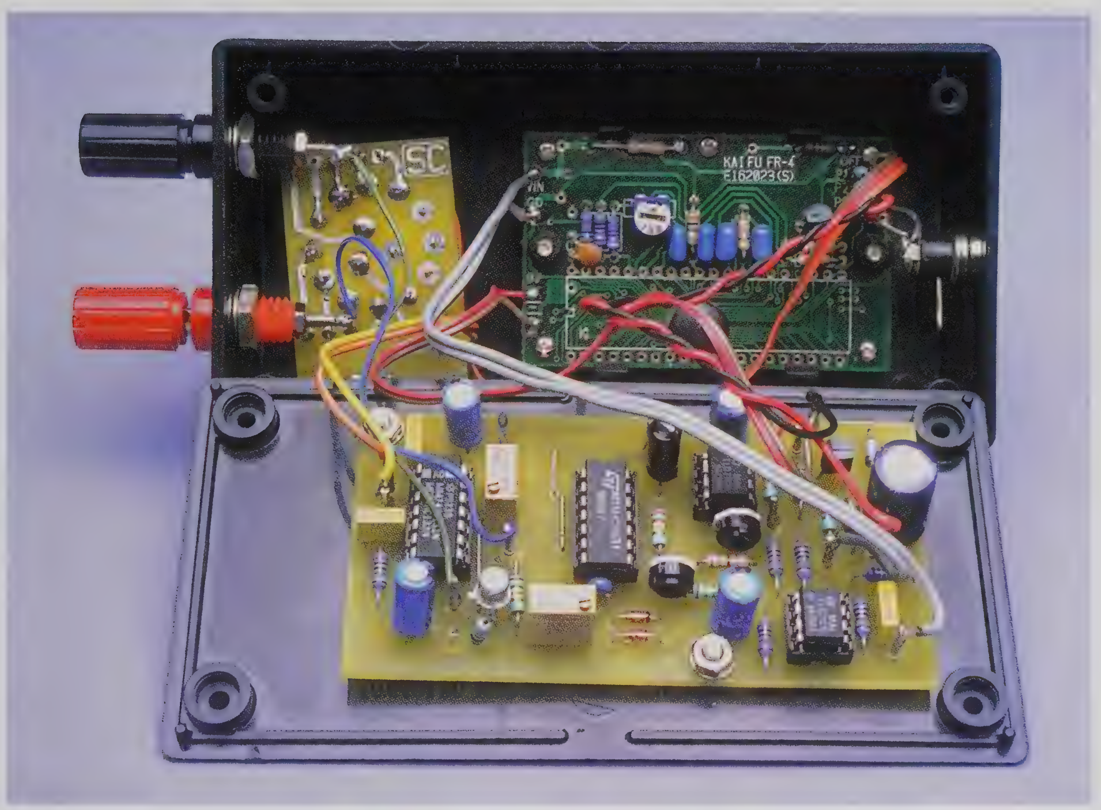
Once everything fits OK, wire the boards together following Fig.4 carefully. Make the leads long enough to be able to test the unit on the bench but not too long or they will be a nuisance when assembling the boards into the case.

When all the wiring is complete, check your work carefully and then apply power to the unit. The display should light and you should be able to make some measurements on capacitors although the readings probably won't be too close to the mark at this stage. It will be need to be calibrated.

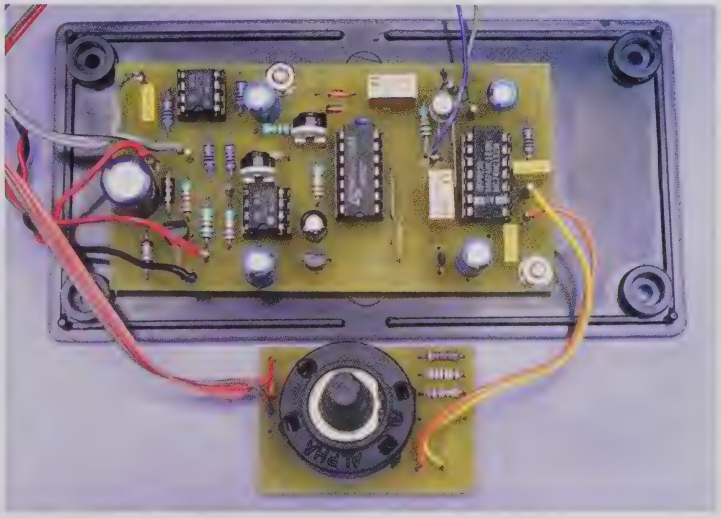
Calibration procedure

Now that you have a working capacitance meter how do you calibrate it? We have used 1% resistors on the range switch, so range-to-range accuracy should be within 1%. The basic accuracy of the instrument is set by the .01μF capacitor at the input of IC1a, along with VR2 and the associated 15kΩ resistor. The input thresholds of IC1 also affect the accuracy. These input thresholds can have a variation in excess of 1V from device to device, when using a 5V supply.

If we could get a precise .01μF capacitor we could specify an exact resistor value to replace the 15kΩ resis-



These two photos show how the PC boards and the LCD module all fit inside the plastic case. Note that the LCD module is optional – see text.



tor and trimpot VR2. Unfortunately, this would not solve the input threshold variation problem. As well, virtually all MKT capacitors have 10% tolerance (K), so we accept the supplied value of the capacitor and adjust the trimpot to calibrate the meter.

Having said all this, we still need an accurately known value of capacitor to carry out the calibration. One way is to obtain five or more of the same value (preferably .015μF or .018μF) and measure them all using the uncalibrated meter. Having measured them, add up the values and calculate the average and then use the capacitor which is closest to the average as the calibration unit. The problem with this method is that the whole batch could have its tolerance in the same direction.

If you have a digital multimeter there is a much better way. Power up an AC plugpack and set your DMM to read AC volts. Connect a 150kΩ resistor and a .015μF or .018μF capacitor in series across the AC output. Measure the AC voltage across each. We then use the formula shown in Fig.5 to calculate the capacitor value.

By measuring the voltage across the

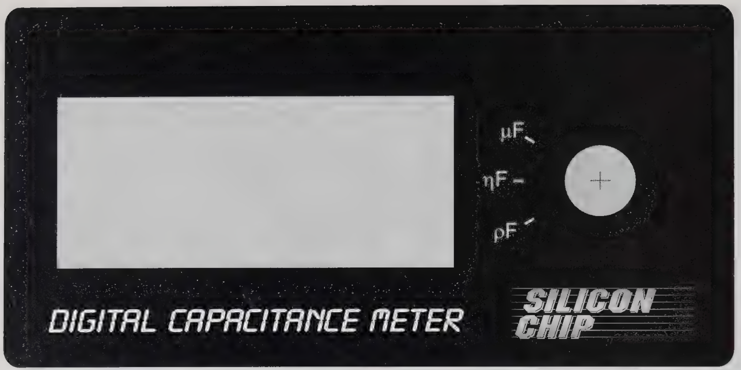


Fig.6: this actual size artwork for the front panel can be used as a drilling template for the switch and the display cutout.

resistor we can calculate the current through the capacitor and we then divide the capacitor voltage by the capacitor current to find its impedance. This method should give you an accuracy better than 2%, depending on your multimeter's AC performance, although it does assume that the mains frequency is exactly 50Hz.

Testing

Once you know the capacitor's value you can use it to do the calibration. Firstly, with power applied and nothing connected to the input terminals, connect your multimeter to pins E & F on the main PC board.

Adjust trimpot VR1 until the DC voltage at pin 11 of IC2 is a minimum (5-10mV depending on the setting of VR3). Note that it dips to a minimum then rises again. Then adjust VR3 until the meter reading is 0mV.

Connect the known capacitor to the input terminals and, on the appropriate range, adjust trimpot VR2 for the correct reading. If you get close but cannot reach the value, add an extra capacitor in parallel with the .01µF capacitor on pin 2 of IC1, as explained in the fault finding section.

If you elected to use the Digital Panel Meter, carry out the calibration described above, then adjust VR4 for a zero reading with no capacitor connected. This done, connect the standard capacitor across the terminals and adjust the trimpot on the panel meter's PC board until the correct reading is displayed.

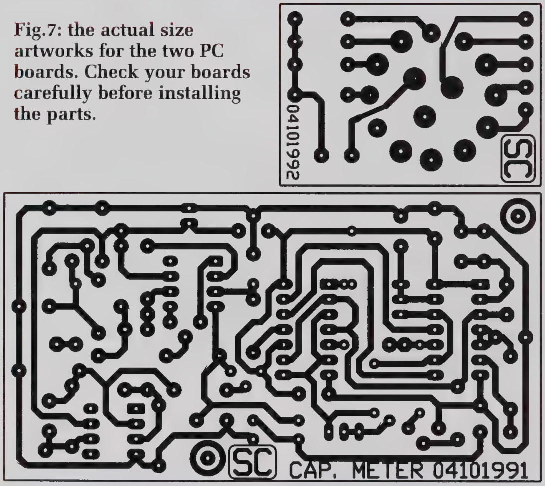


Fig.7: the actual size artworks for the two PC boards. Check your boards carefully before installing the parts.

Fault finding

The first check to make, if the circuit is not working, is to measure the DC voltages. Check that the input to REG1 is around 9V with either battery or plugpack supply. Its output should be 5V ±5%. If any of these voltages are missing, you will have to trace from where they are present along the track (or tracks) to where they vanish.

Obviously, if the 9V battery supply measures low or 0V, disconnect it quickly as you may have a short and the battery will be rapidly flattened. For this reason, it is wise to use a bench power supply with an ammeter, if you have one, to do the initial testing.

Next, check the negative voltage at pin 4 of IC3. This voltage will vary depending on the current drawn by IC4 but it should be somewhere around -3V. If there is no negative voltage, it is likely that IC1b is not oscillating, so check the soldering and tracks around this device and the polarities of D3 and D4. When it is oscillating the DC voltage at pin 6 should be about +2.3V. The AC voltage should be around 2.75V.

Similar DC and AC readings should be present at pins 3 and 12 of IC1 and pins 3, 6 & 8 of IC2. If you discover any voltages that are wildly different then you have found one (or all) of your faults.

If you cannot adjust trimpot VR2 to get the meter reading high enough then add a 470pF or .001µF capacitor in parallel with the .01µF capacitor at pin 2 of IC1. Provision has been made on the PC board for this additional capacitor. The value will depend on all the component tolerances, as previously explained.

Using it

Always start from the pF range and turn the switch clockwise if the readout indicates over-range.

The pF range covers from 1-1999pF; the nF range covers 0.1nF to 199.9nF (or if you prefer .0001µF to .1999µF); and the last range covers .001µF to 1.999µF. If you don't like nanofarads, and would like the middle range to display µF, disconnect the P1 decimal point wire from S1b. Of course, you will have to alter the label lettering to agree with this modification. **SC**

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005.6
mV
DC
VALUE per mV
0.1Ω
0.01Ω
1Ω
1mΩ
POWER
LOW OHMS TESTER
SILICON CHIP

This Low Ohms Tester plugs directly into a digital multimeter and can accurately measure resistances down to 0.01Ω. It's easy to build and runs off a 9V battery.

By JOHN CLARKE

Low ohms adaptor for digital multimeters

THE ABILITY TO measure low resistance values is necessary when items such as meter shunts, loudspeaker crossover networks, inductors and contact resistances are to be checked.

Unfortunately, a standard digital multimeter (DMM) can only accurately measure resistances down to about 5Ω. Resistors with lower values will give misleading results due to a lack of meter resolution. A couple of examples will serve to illustrate this point.

First, let's assume that a resistance of 0.1Ω is to be checked on a standard 3-1/2 digit multimeter. In this case, you would have to switch down to the 200Ω range (the lowest you can select) and the reading would be 0.1Ω ±1 digit (ie, ±0.1Ω). In other words, the resolution of the DMM limits the accuracy of the reading to ±100% which is ridiculous.

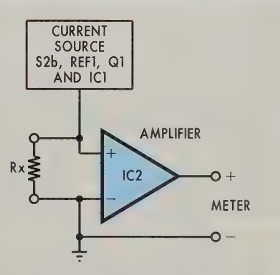

Fig.1: block diagram of the Low Ohms Tester. It works by applying a constant current through the test resistor (Rx). The voltage across Rx is then measured using a DMM.

This situation quickly improves with increasing resistance values. For example, a value of 1Ω will result in a reading of 1.0Ω ±1 digit, assuming that the 200Ω range is used. This represents an accuracy of 10%. For values above 10Ω, the accuracy of the instrument will be 1% or better since the resolution of the reading is considerably improved.

This Low Ohms Tester overcomes the limitations of conventional digital

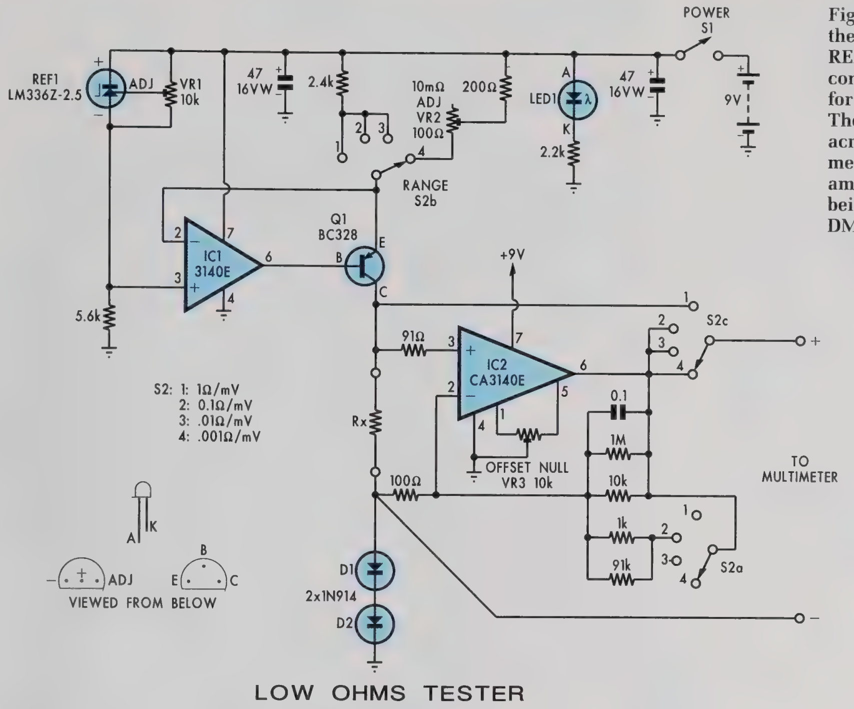
POWER
S1
REF1
LM336Z-2.5
ADJ
VR1
10k
47
16VW
2.4k
10mΩ
ADJ
VR2
100Ω
200Ω
LED1
A
K
2.2k
47
16VW
9V
RANGE
S2b
Q1
BC328
B
E
C
IC1
3140E
5.6k
+9V
IC2
CA3140E
91Ω
Rx
100Ω
OFFSET NULL
VR3 10k
0.1
1M
10k
1k
91k
S2c
S2a
TO
MULTIMETER
D1
D2
2x1N914
S2: 1: 1Ω/mV
2: 0.1Ω/mV
3: .01Ω/mV
4: .001Ω/mV
A
K
B
ADJ
E
C
VIEWED FROM BELOW
LOW OHMS TESTER

Fig.2: the full circuit for the Low Ohms Tester. REF1, IC1 and Q1 form a constant current source for the test resistor Rx. The resulting voltage across Rx is then either measured directly or amplified by IC2 before being applied to the DMM.

multimeters for low values of resistance. It does this by applying a constant current through the test resistor Rx. The resulting voltage developed across Rx is then amplified and applied to the DMM which is set to read in millivolts. Fig.1 shows the basic scheme.

As shown in the photos, all the circuitry is housed in a compact plastic case. This carries a power switch, a 4-position range switch and two binding post terminals for the test resistor. The output leads emerge from the top of the instrument and are fitted with banana plugs. These simply plug into the COM and VΩ terminals of the DMM.

Main Features

- Measures from 0.01Ω to 100Ω
- Four ranges
- Outputs to a digital multimeter
- Battery operated

The output from the Low Ohms Tester is a voltage (in mV) which is directly proportional to the resistance being measured. In practice, you simply multiply the reading on the DMM by the range setting on the tester to get the correct value. For example, a DMM reading of 5.6mV when the 0.1Ω range is selected is equivalent to 5.6 x 0.1 = 0.56Ω.

From this, it follows that if the 1Ω range is selected, the reading on the DMM is directly equivalent to the value in ohms.

Values from 100Ω down to 0.01Ω can be measured via the tester. Below this, errors start to be significant due to contact and lead resistance.

Values above 100Ω can also be measured via the tester but this is rather pointless. That's because the DMM alone can be used to accurately measure values above this figure.

Circuit details

Refer now to Fig.2 for the complete

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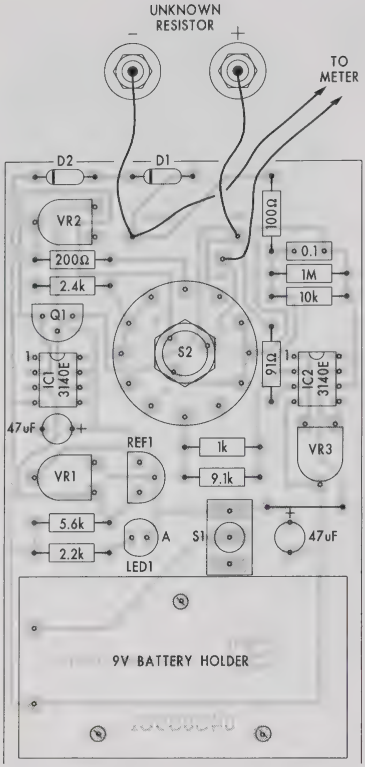


Fig.3: install the parts on the PC board and complete the wiring as shown here.

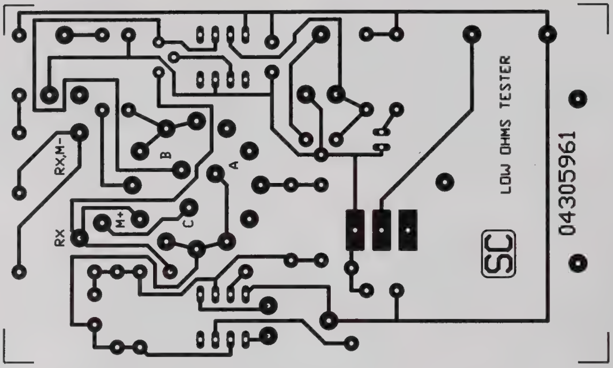


Fig.4: this is the full-size etching pattern for the PC board.

circuit of the Low Ohms Tester. It consists of a constant current source (which supplies the current through test resistor Rx) plus an amplifier stage to drive the DMM.

IC1, REF1 and Q1 are the basis of the constant current source. REF1 is a precision voltage source which provides a nominal 2.490V between its "+" and "-" terminals. This device is connected between the positive supply rail and ground via a 5.6kΩ current limiting resistor. VR1 allows the reference voltage to be adjusted slightly and is used for calibration.

Op amp IC1 and transistor Q1 function as a buffer stage for REF1. Because this stage is a voltage follower, the voltage on Q1's emitter will be the same as the voltage on pin 3 of IC1. This means, in turn, that the voltage across the resistance selected by S2b is equal to the REF1 voltage.

As a result, a constant current flows through the selected resistance and this current also flows through Q1, test resistor Rx and diodes D1 & D2 to ground.

In greater detail, when S2b selects positions 1, 2 or 3, the 2.4kΩ resistor is in circuit and so has the REF1 voltage across it. If REF1 is adjusted to 2.4V, then 1mA will flow through the resistor and thus through Q1 and Rx. Conversely, when S2b selects position 4, the constant current source delivers 10mA to Rx (assuming that VR2 is correctly set).

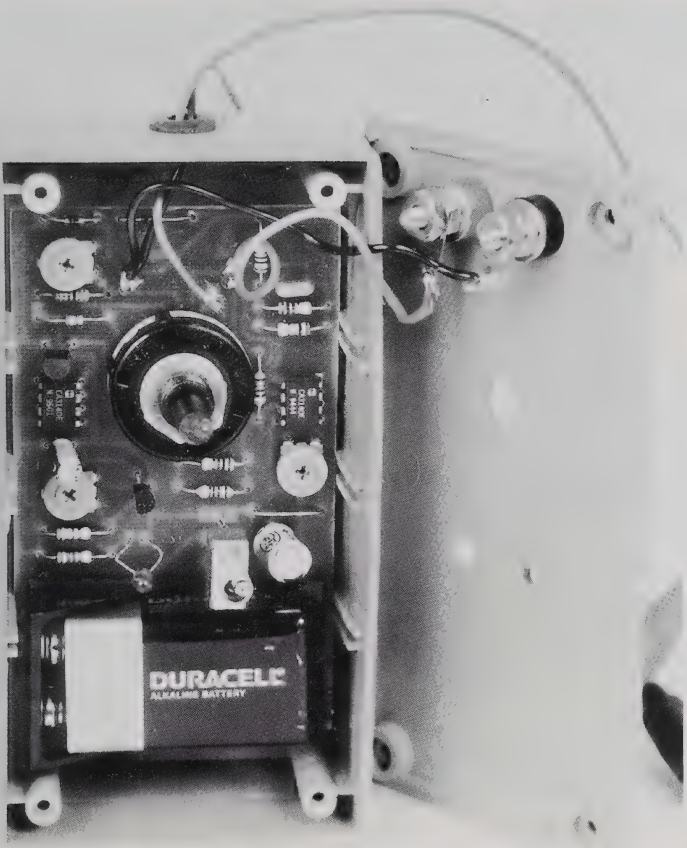
IC2 functions as the amplifier stage. This operates with a gain of either x10 or x100, as set by switch S2a. Switch S2c selects between the collector of Q1 and the amplifier output at pin 6.

Thus, when position 1 is selected, the amplifier is bypassed and the DMM directly monitors the voltage across Rx. Because the constant current source supplies 1mA through Rx in this position, the reading in millivolts is directly equivalent to the value of Rx in ohms.

Conversely, when positions 2, 3 or 4 are selected, IC2 amplifies the voltage across Rx and drives the DMM via its pin 6 output. IC2 operates with a gain of 10 when position 2 is selected and a gain of 100 when positions 3 or 4 are selected. These gain values are

Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	1MΩ	brown black green brown	brown black black yellow brown
☐	1	91kΩ	white brown orange brown	white brown black red brown
☐	1	10kΩ	brown black orange brown	brown black black red brown
☐	1	5.6kΩ	green blue red brown	green blue black brown brown
☐	1	2.4kΩ	red yellow red brown	red yellow black brown brown
☐	1	2.2kΩ	red red red brown	red red black brown brown
☐	1	1kΩ	brown black red brown	brown black black brown brown
☐	1	200Ω	red black brown brown	red black black black brown
☐	1	100Ω	brown black brown brown	brown black black black brown
☐	1	91Ω	white brown black brown	white brown black gold brown



The PC board carries nearly all the parts and is mounted by clipping it into the guide notches of a standard plastic case. Note that the locking collar of the rotary switch (under the mounting nut) must be set to position 4, as described in the text.

set by the 1MΩ, 10kΩ, 1kΩ & 91kΩ resistors in the feedback network.

In position 2, all four resistors are connected in parallel to give a feedback resistance of 900Ω. IC2 thus operates with a gain of 1 + 900/100 = 10. In the other three positions, only the 1MΩ and 10kΩ resistors are connected and these give a feedback resistance of 9.9kΩ. The gain is now 1 + 9900/100 = 100.

Note that the 0.1μF capacitor is always connected across the feedback path, to reduce any high frequency noise.

The 91Ω resistor at pin 3 matches the impedance seen by this input to that seen by the pin 2 input. This ensures that equal currents flow in the two op amp inputs and this in turn minimises the output offset voltage. VR3 nulls out any remaining offset voltage and is adjusted so that the DMM reads 0mV when Rx is 0Ω (ie, when the test terminals are shorted together).

One interesting point is that the lower end of Rx is two diode drops above ground, due to series diodes D1 and D2. This ensures that IC2 operates correctly when the output is only 1mV above the lower Rx connection point.

Power for the circuit is derived from a 9V battery via power switch S1. Two 47μF capacitors across the supply provide decoupling and lower the impedance of the 9V rail, while LED1 provides power on/off indication.

Construction

Most of the parts are mounted onto a small PC board coded 04305961 and measuring 60 x 100mm. The board clips into the integral side pillars of a plastic case measuring 130 x 66 x 43mm.

Begin construction by checking the PC board for shorted tracks or small breaks. Check also that it clips neatly into the case. Some filing of the PC board sides may be necessary to allow a good fit without bowing the case sides.

Begin the board assembly by installing the PC stakes. These are located at the three external wiring points and at the connections for switch S1. This done, insert the single wire link (it sits immediately beneath VR3).

Next, install the resistors (see table for colour codes), then install the diodes and ICs, taking care to ensure that they are oriented correctly. The capacitors can go in next – note the polarity of the two 47μF electrolytic types.

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Parts List

1 PC board, code 04305961, 60 x 100mm
1 front panel label, 62 x 125mm
1 plastic case, 130 x 66 x 43mm
1 9V battery holder
1 9V battery
1 SPDT toggle switch (S1)
1 3-pole 4-way PC mount rotary switch (S2)
2 10kΩ horizontal trimpots (VR1,VR3)
1 100Ω horizontal trimpot (VR2)
1 12mm knob
2 banana plugs
2 banana panel sockets
6 PC stakes
1 6mm ID rubber grommet
1 20mm length of 0.8mm tinned copper wire
1 300mm length of hook-up wire
3 2.5mm screws and nuts

Semiconductors
2 CA3140E Mosfet input op amps (IC1,IC2)
1 BC328 PNP transistor (Q1)
1 LM336Z-2.5 reference (REF1)
2 1N914, 1N4148 signal diodes (D1,D2)
1 5mm red LED (LED1)

Capacitors
2 47µF 16VW PC electrolytic
1 0.1µF MKT polyester or monolithic ceramic

Resistors (0.25W, 1%)
1 1MΩ
1 91kΩ
1 10kΩ
1 5.6kΩ
1 2.4kΩ
1 2.2kΩ
1 1kΩ
1 200Ω
1 100Ω
1 91Ω
1 1Ω 1% (for calibration)

Miscellaneous
Hook-up wire, tinned copper wire.

REF1 and Q1 can now both be installed. Note that these two devices look the same so make sure that you don't get them mixed up. LED1 is mounted on the end of its leads so that it will later protrude through a matching hole in the front panel. For the same reason, switch S1 is soldered to the top of the previously installed PC stakes.

Rotary switch S2 is mounted directly on the PC board. Ensure that it has been pushed fully home and sits flat on the PC board before soldering its pins. This done, loosen the switch mounting nut, lift up the star washer and rotate the locking collar to position 4. This turns what was a 12-position rotary switch into a 4-position rotary switch. Check that the switch operates correctly, then do the nut up tight again so that the locking collar is secured.

The board assembly can now be completed by mounting the trimpots and fitting the battery holder. Note that VR2 is a 100Ω trimpot, while VR1 and VR3 are both 10kΩ types so be careful with the values here. The battery holder is secured to the PC board using the 2.5mm mounting screws supplied with it.

Final assembly

It's now just a matter of installing the board and the ancillary bits and pieces in the case. First, attach the front panel label, then drill holes for the LED, switches S1 & S2, and the two test terminals. A hole will also have to be drilled in the top of the case to accept a small grommet.

The PC board can now be clipped into the case, the test terminals mounted in position and the wiring completed as shown in Fig.3. This done, check that the switches and the LED line up with the front panel holes. Adjust the height of the LED and switch S1 if necessary, so that they fit correctly.

The leads to the meter run through the grommetted hole in the top of the case. Keep these leads reasonably short and terminate them with banana plugs. It will be necessary to trim the shaft of switch S2, so that the knob sits close to the front panel.

Test & calibration

Now for the smoke test. Apply power and check that the LED lights (if it doesn't, check that the LED has been oriented correctly). Now check the supply voltages on IC1 and IC2 using a multimeter. In each case, there should be about 9V between pins 7 and 4.

If everything is OK so far, check the voltage between pin 3 of IC1 and the positive supply rail (ie, the voltage across REF1). Assuming VR1 is centred, you should get a reading of 2.4-2.5V. Pin 2 of IC1 should be at the same voltage as pin 3.

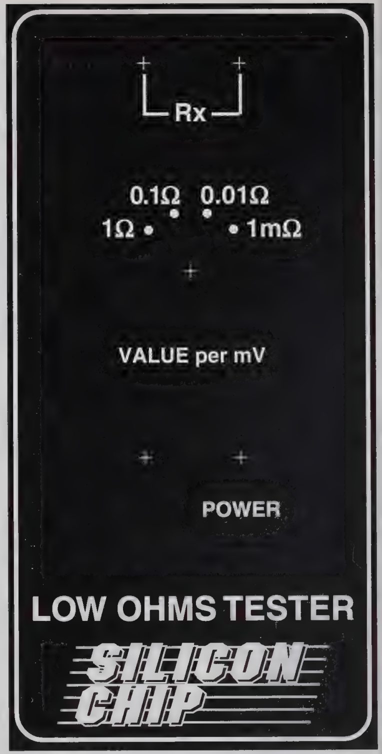


Fig.5: this full-size artwork can be used as a drilling template for the front panel.

To calibrate the unit, follow this step-by-step procedure:

(1) Monitor the voltage across REF1 and adjust VR1 for a reading of 2.4V (this sets the constant current.

(2) Plug the Low Ohms Tester into the DMM and short the Rx test terminals using a short length of 1mm tinned copper wire.

(3) Select the 0.01Ω range and adjust VR3 for a reading of 0mV on the DMM. Check for a similar reading when the 1mΩ range is selected.

(4) Connect a 1Ω 1% resistor between the test terminals, select the 0.01Ω range and adjust VR1 again for a reading of 100mV.

(5) Select the 1mΩ range and adjust VR2 for a reading of 1V.

(6) Short the test terminals again and verify that the DMM reads close to 0mV for all ranges.

That completes the calibration procedure. The lid can now be attached to the case, the knob fitted to S2 and the unit pressed into service. **SC**

3-LED LOGIC PROBE

Ever been chasing a problem on a digital logic board and wasted a lot of time because you were too lazy to get the scope out and plug it in? What, you don't even own one? This logic probe will prove invaluable in digital fault finding and only costs a few dollars.

By RICK WALTERS

ALL RIGHT, WHAT is a logic probe? A logic probe is a small hand-held device which indicates the logic state at its input probe. The logic level should only be ground (low) or at the positive supply (high) but a faulty device can have an output level somewhere around half the supply. Ideally, a logic probe should indicate all three circuit states and that is what this simple design does.

The probe has three LEDs which are readily visible whether you are right or left-handed. The red one indicates a low level, the green one a high level and the yellow one is lit whenever the level changes from high to low.

You may wonder why we bothered with the yellow indication. We have just stated that if the level is low, the red LED will light, if the level is high the green one will be lit, and if the level is changing from high to low then obviously both will light.

The fault condition described above can sometimes cause both LEDs to come on and this would give us a false indication. The yellow LED needs a full high-low transition to light it, thus eliminating any false indication.

How does it work?

As you can see from the circuit of Fig.1 there is not much to it. A 4001 quad 2-input NOR gate is used as it lets us make a monostable by cross-coupling two gates. We'll get to that in a moment, so let's start at the input.

The probe tip is connected directly to pins 5 & 6 of IC1b. The 10MΩ resistor holds those pins low and prevents the input capacitance being charged and staying high when the probe encounters a momentary high level. The output of IC1b is fed to pins 1 & 2 of IC1a which in turn, drives the LEDs. Note that since each gate effectively inverts its input and there are two signal inversions via these gates,

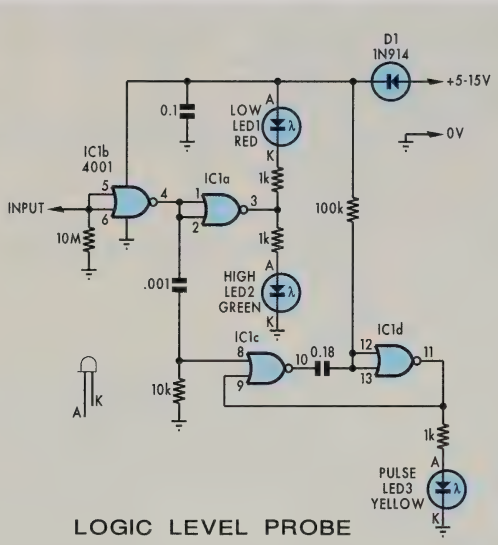


Fig.1: the circuit uses a 4001 quad 2-input NOR gate to indicate high, low or fault logic conditions.

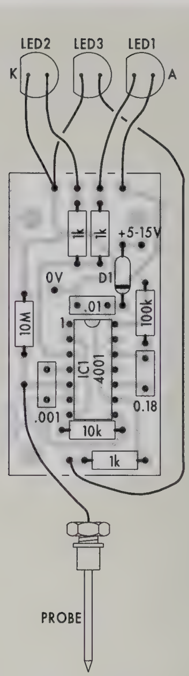


Fig.2: not shown on this wiring diagram are the positive and negative supply leads which clip onto the circuit being measured.

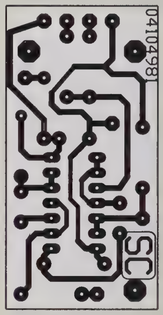


Fig.3: actual size artwork for the PC board.

the output of IC1a is in phase with the input.

Thus when the input is low, the output of IC1a is low and the red LED will be lit. When the input goes high, the red LED will go out and the green one will light.

The output of IC1b is also coupled through a .001µF capacitor to one input of IC1c. This input is held low by the 10kΩ resistor to ground. IC1c's output, pin 10, is coupled via the 0.18µF capacitor to the inputs of IC1d. These inputs are held high by the 100kΩ resistor which means the output at pin 11 will be low.

A low to high transition at the output of IC1b will pull pin 8 of IC1c high and consequently pin 10 will go low. This will pull pins 12 & 13 low, taking pin 11 high and thus turning on LED3. As pin 11 is also connected to pin 9 of IC1c, it will hold the output of IC1c low even after the initial logic signal at pin 4 has charged the .001µF capacitor.

The yellow LED will stay lit until the voltage on the 0.18µF capacitor, which is charging through the 100kΩ resistor, reaches the switching threshold of IC1d. When it is reached, the output of IC1d will go low, the yellow LED will extinguish and the output of IC1c will go high again.

Thus each high to low input transition will flash the yellow LED for 18ms. At low frequencies this is readily apparent but as soon as the input frequency is high enough, the LED will appear to be lit continuously.

So just to sum up, if the red or green LED is on, the logic circuit being measured is indicating a valid condition (ie, low or high), although if you want a high and you get a low you obviously have a problem.

Power for the Logic Probe comes from the circuit being measured and can be anywhere between 5V and 15V DC. Diode D1 protects the logic probe if you accidentally make the wrong supply connections (ie, wrong polarity) to the circuit.

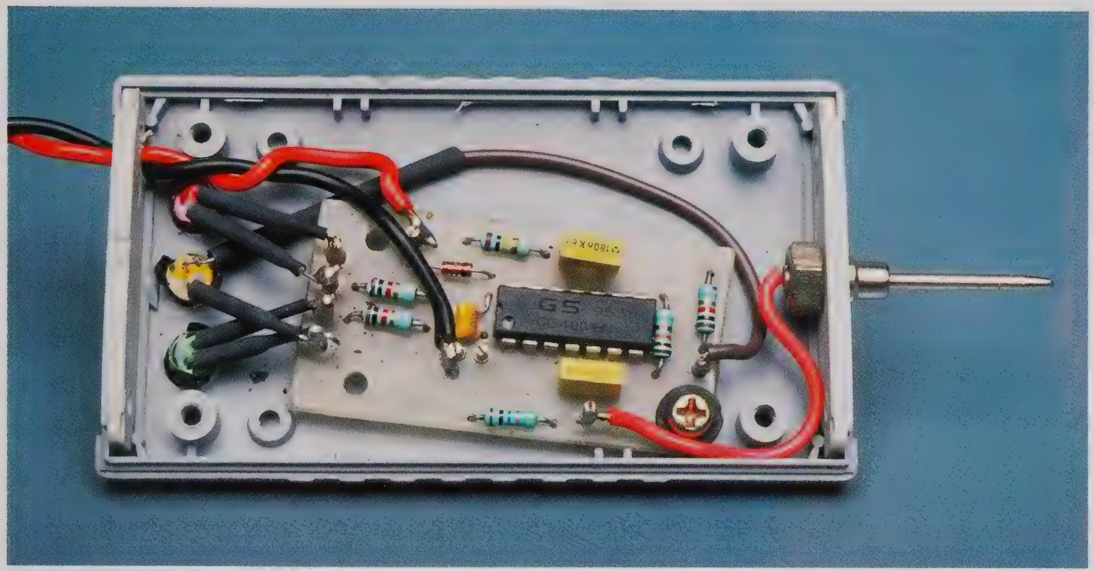
PC board assembly

We made the PC board as small as possible, so you could fit it into a smaller case than the one we used, if you have one.

We would have preferred a slightly narrower rectangular case but the one we used is readily available and inexpensive. On the positive side, if you have large hands, the size and shape of the specified case is quite convenient to handle.

The assembly details for the Logic Probe are shown in Fig.2 and are quite straightforward. Don't use an IC socket for the 4001 as there is not much depth in the case we have specified. Use the PC stakes as they are a convenient connection for the LED leads. Keep the wires close to the PC board when you solder them and cut the top off the stakes or else they will prevent you from assembling the case properly.

Drill the three holes in the case for the LEDs and file a notch in the end

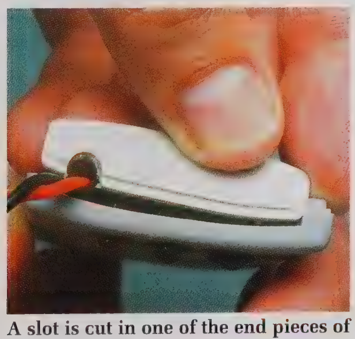


This is the view inside the Logic Probe case. Note that the leads to the three LEDs must be sleeved to avoid the possibility of shorts.

panel to bring the power wires out. Make it small enough so that the wires are lightly clamped when the case is screwed together.

We secured the board inside the case by using a small self-tapping screw into one of the integral pillars. However, the pillar is very short and you must be careful not to tighten the screw too much otherwise it will penetrate right through the case. If you look closely at the inside photo of the Logic Probe you will note that we have placed a black fibre washer underneath the screw head to avoid this problem.

Another point to note about the inside photo is that the LEDs should have sleeving on their leads to avoid the possibility of shorts.



A slot is cut in one of the end pieces of the case for the power supply leads.

We used a probe from an old multimeter lead as the input prod but failing this, a nail or a small gauge screw with a filed point could be pressed into service. I'm sure your ingenuity won't fail you here.

Testing

Connect the power leads to 5-12V and the red LED should immediately light. If it doesn't, you probably have its leads reversed. Don't worry though, just make the connections correctly and it should work properly.

Use your multimeter to measure the voltage at pin 3 of IC1a. It should be at ground potential; ie 0V.

Now put the probe on the positive supply. This should extinguish the red LED and light the green one.

As you remove the probe from the supply, you should see the yellow LED flash briefly. Tap the probe on and off a few times until you see it.

The beauty of this device is that if you connect it to a logic PC board with a 5V supply, all the functions work as described. But it can be connected to any supply up to 15V with safety and the logic thresholds will move to track the supply.

It will work with all "C" & "HC" devices as well as the older TTL range. The upper frequency depends on the supply voltage. With a 5V supply the 4001 should indicate up to 2-3MHz and around three times this frequency with a 15V supply. **SC**

Parts List

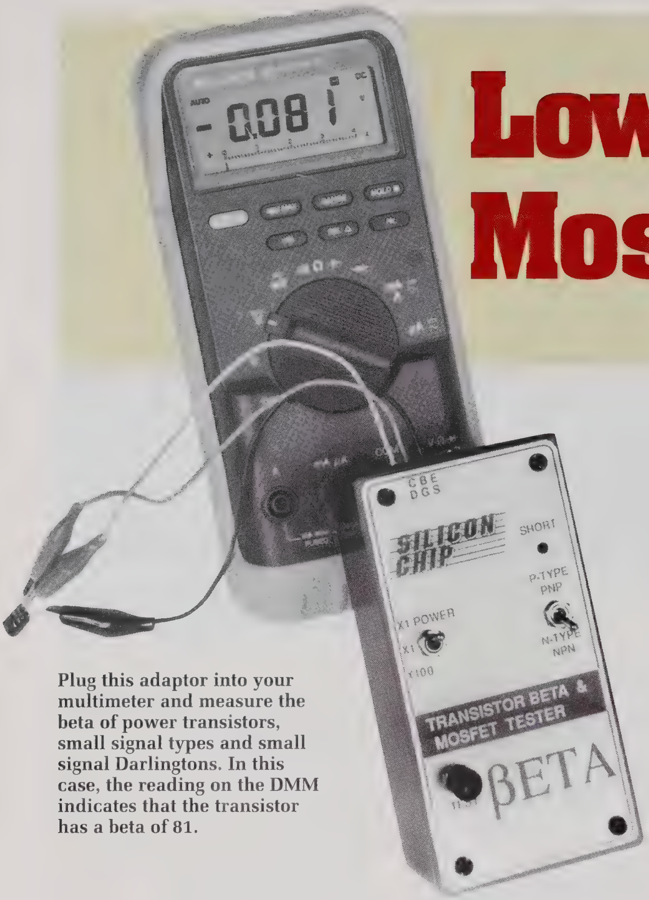
1 PC board, code 04104981, 50 x 26mm
1 small plastic case, Jaycar HB-6030 or equivalent
1 red crocodile clip
1 black crocodile clip
3 5mm LED bezel clips
8 PC stakes
1 6mm long self-tapping screw
1 fibre washer (see text)
0.5m red hookup wire
0.5m black hookup wire

Semiconductors
1 4001 quad 2-input NOR gate (IC1)
1 1N914 small signal diode (D1)
1 5mm red LED (LED1)
1 5mm green LED (LED2)
1 5mm yellow LED (LED3)

Capacitors
1 0.18μF MKT polyester
1 0.1μF MKT polyester or monolithic ceramic
1 .001μF MKT polyester

Resistors (0.25W, 1%)
1 10MΩ
1 100kΩ
1 10kΩ
3 1kΩ

Low-cost tran
Mosfet tester



Plug this adaptor into your multimeter and measure the beta of power transistors, small signal types and small signal Darlingtons. In this case, the reading on the DMM indicates that the transistor has a beta of 81.

This handy tester is designed to plug into a digital multimeter to provide an accurate measurement of transistor beta, to values up to 50,000 & more. You can use it to test small signal, power & Darlington transistors &, as a bonus, it will also check Mosfets.

By JOHN CLARKE

If you need to use transistors from your junk box for your projects, it is a good idea to test them before soldering them into circuit. Actually, this is a good idea even if you have just purchased the transistors because it can stop you from soldering the wrong type into circuit. But now that many digital multimeters incorporate a simple transistor tester, why would you want to build this adaptor?

Well, there are several drawbacks to the typical "transistor test" facility in most digital multimeters. First, most will not measure transistor gains in excess of 1000. Most ordinary transistors have a beta of less than 1000 but many Darlington transistors have a beta far in excess of 1000 – up to 50,000 or more, in some cases. Also the fact that Darlington transistors have a base-emitter voltage drop of 1.2V or more and they incorporate internal base-emitter resistors means that the base current from the DMM test circuit may be less than it should be, another source of inaccuracy.

Another drawback involves power transistors. These typically require much more base current than small signal transistors and so beta tests of a power transistor using a DMM can often give misleading results.

On the other hand, many of the top brand digital multimeters do not have a transistor test facility at all and this is where the SILICON CHIP transistor tester comes into its own.

Transistor gain

You can use the tester to match transistors for gain or to decide whether an unknown device is a Darlington (very high gain) or a standard transistor. You can also find out the transistor pin-outs by trying all connection possibilities until a valid gain measurement is found. Similarly, you can determine whether the device is NPN or PNP by finding the polarity which gives a gain reading.

Mosfets are used extensively in SILICON CHIP circuits these days and testing them can be difficult. With this tester, you can obtain valuable information about the condition of a Mosfet. The test is not a g_m measurement but it will give a good indication of Mosfet gain.

The tester is housed in a small plastic case. Three flying leads with alligator clips are clipped to the device to be tested. On the underside of the

sistor & for DMMs

Main Features

- Measures beta from 1 to over 50,000
- Plugs directly into a digital multimeter for beta readings
- Measures NPN and PNP transistors
- Tests N-type and P-type Mosfets
- Two test base currents: 10µA and 1mA
- High beta accuracy and resolution at measured current
- Battery operated
- Suitable for high impedance (>10MΩ) multimeters
- Short indication

case are two banana plugs which insert directly into the "VΩ" and "common" inputs. There are two toggle switches; one is the NPN (N-type)/ PNP (P-type) switch to select the device polarity and the other is the 3-position range switch. The digital multimeter is turned on and a DC range selected, normally 2V to start. Then you press the button and the meter gives a reading. To convert the reading to beta, just take the reading in millivolts. For example, if you are on the 2V range and the reading is 0.695V or 695mV, the transistor beta is 695.

Alternatively, if the 200mV DC range has been selected and the reading is 115mV, then the beta is 115.

Power is consumed only while the Test button is pressed. If you want to hold the reading on your multimeter, press the "hold" button if it has one. That is how we stored the reading for the setup shown in the photograph accompanying this article.

Multiplier switch

The 3-position multiplier toggle switch needs some explanation. The position marked "X1 POWER" is used for testing power transistors and power Darlingtons. The other two settings are used for small signal transistors. The centre position marked "X1" gives a result as described; ie, the reading in mV is the beta. When on the "X100" setting, the readings are multiplied by 100 to give the actual result. This position is intended for small signal Darlington transistors which can typically have a beta of 30,000 or more.

Mosfets are measured in a similar

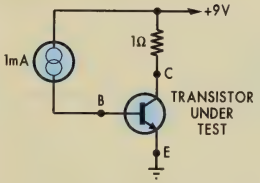


Fig.1: this is the basic beta test setup with a fixed current supplied to the base of the transistor. If 100mV appears across the 1Ω resistor, the collector current is 100mA & the beta is 100.

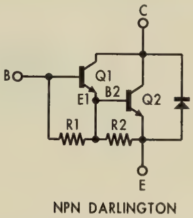


Fig.2: typical Darlington power transistors have internal base-emitter resistors which means that a minimum base current of about 1mA is required to turn them on. Most beta testers in DMMs cannot supply this much base current.

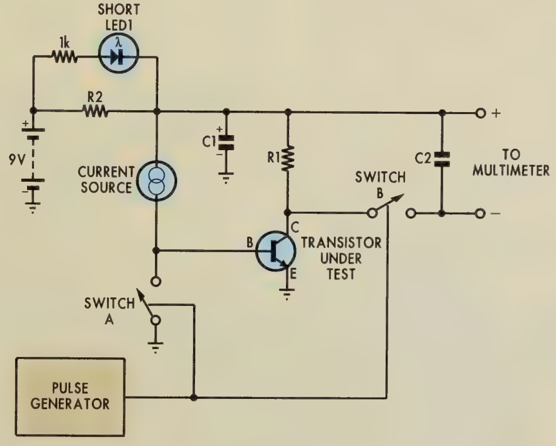
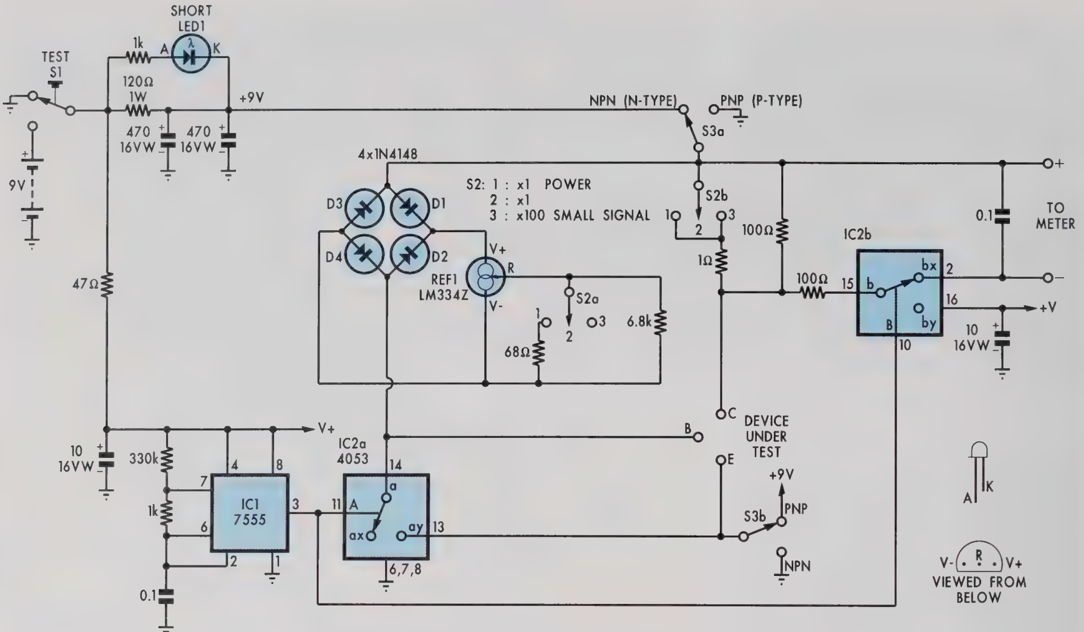


Fig.3: this circuit shows the principle of operation of the Beta Tester. The current source is shunted to ground by switch A. When switch A opens, the current source drives the base of the transistor & a voltage proportional to the collector current is developed across R1. Switch B & capacitor C2 form a "sample and hold" circuit which stores the voltage developed across R1 so that it can be read as a DC voltage by the multimeter.


SHORT
LED1
TEST
S1
1k
A
K
120Ω
1W
+9V
470
16VW
470
16VW
9V
NPN (N-TYPE)
PNP (P-TYPE)
S3a
4x1N4148
D3
D1
D4
D2
S2: 1 : x1 POWER
2 : x1
3 : x100 SMALL SIGNAL
S2b
1
2
3
100Ω
IC2b
0.1
TO
METER
+
−
V+
R
V-
REF1
LM334Z
S2a
6.8k
68Ω
1Ω
100Ω
15
b
bx
by
2
16
B
10
+V
10
16VW
47Ω
C
DEVICE
UNDER
TEST
B
E
V+
IC2a
4053
14
a
A
ax
ay
13
11
6,7,8
330k
1k
IC1
7555
4
8
7
6
3
2
1
10
16VW
0.1
+9V
PNP
S3b
NPN
A
K
V-
R
V+
VIEWED FROM
BELOW

TRANSISTOR BETA AND MOSFET TESTER

Fig.4: the circuit of the Beta Tester uses a 7555 astable multivibrator (IC1) & a 4053 analog switch (IC2) to shunt the base current to the transistor.

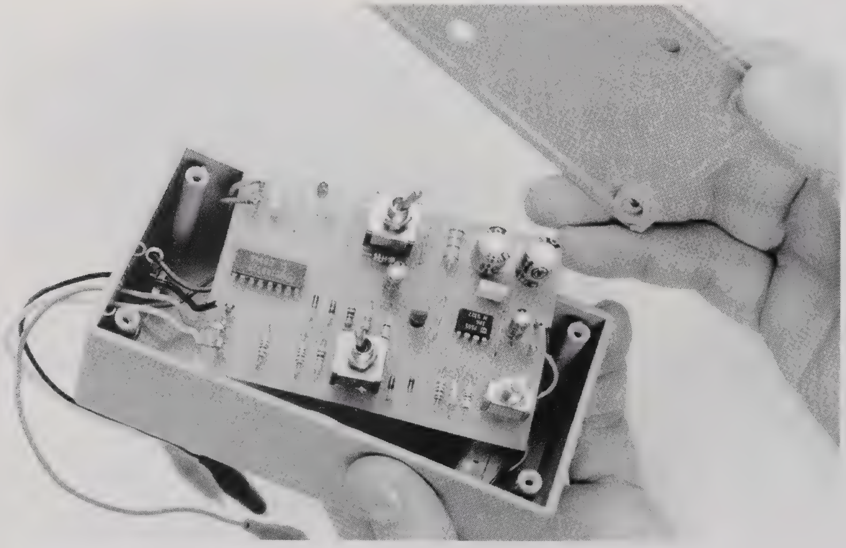
manner to power transistors. A good Mosfet will give a very high gain reading.

If a device being tested has a short between collector and emitter, the "Short" LED will light. The LED will also light when the wrong polarity is selected for Mosfet and Darlington transistors.

Test method

Fig.1 shows the method of gain testing used in the circuit. The transistor under test is connected in a common emitter configuration with a 1Ω resistor for the collector load and a 1mA current source for the base drive. A transistor with a gain of 10 will produce a 10mV drop across the resistor.

However, there are a few problems with this circuit. Firstly, for high gain transistors, a high current will be drawn from the supply and secondly, some transistors will not handle the



The PC board is mounted on the lid of the case & secured to it using the switch nuts. Adjust the LED leads so that it just protrudes through the lid after it is placed in position.

collector current without self-destructing.

Simply reducing the base current and increasing the collector resistor will drop the current but will not solve the problem. This is because we need the 1mA base current to drive power transistors.

Fig.2 shows the internal arrangement of power Darlington transistors. This entails two transistors with the emitter of the first transistor connected to the base of the second transistor. In addition, they also include base-emitter resistors. Resistor R1 can be as low as 1kΩ while R2 is generally smaller again. Since we must develop about 0.7V across the base and E1 of Q1 before transistor Q2 will switch on, the base current into Q1 must be at least 700µA.

Pulse testing

Because we cannot reduce the base current we need to modify the circuit in some other way to curb the excess current which will otherwise be drawn by high-gain transistors. Fig.3 shows how this is done by pulsing the base current with a short duty cycle. By having a long period between each base current pulse to the transistor, the average collector current can be reduced to only a few milliamps. Capacitor C1 lowers the supply impedance so that it can more easily deliver the required high current pulses.

Switch A is normally held closed by the pulse generator and thereby shunts the current source to ground, preventing the transistor from turning on. When switch A opens, the current source drives the base of the transistor and a voltage proportional to the collector current is developed across R1. Switch B and capacitor C2 form a "sample and hold" circuit which stores the voltage developed across R1 so that it can be read as a DC voltage by the multimeter. Hence, when switch A opens, switch B closes and "samples" the resultant collector voltage.

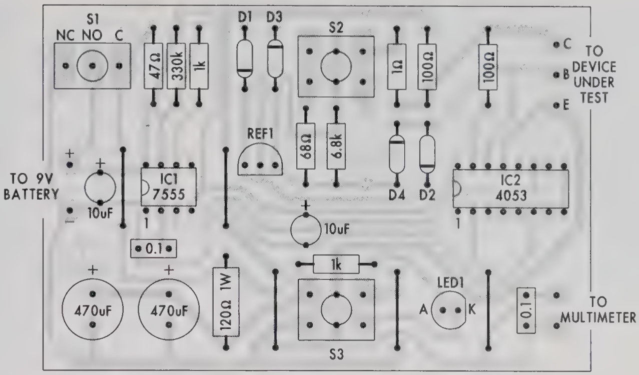


Fig.5: follow this parts layout diagram when installing the parts on the PC board. Note particularly the orientation of the contacts on switch S1 – see text.

Resistor R2 is included for short circuit protection. If a transistor is connected incorrectly or if the collector and emitter leads are shorted together, excess current will otherwise flow. LED1 indicates whenever a short is present and also lights briefly each time the "TEST" button is pressed.

The type of measurement used in the beta tester gives us the DC gain or h_{FE} for the transistor. Mosfet devices are tested in a similar manner to transistors. The current source will charge up the gate to switch on the Mosfet and a voltage proportional to the Drain current will appear across resistor R1.

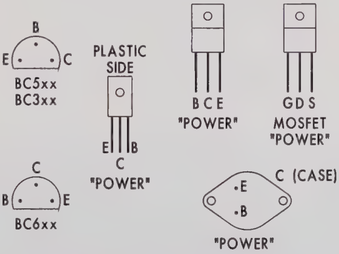


Fig.6: typical pin-outs for various case styles of transistor.

Circuit operation

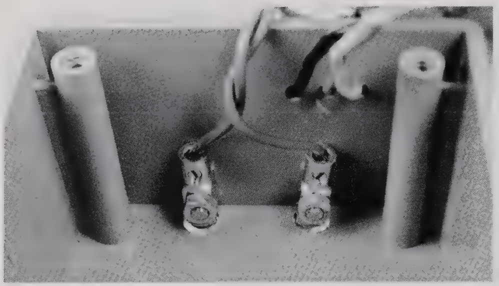
The complete circuit for the Beta Tester is shown in Fig.4. IC1 is a 7555 CMOS timer connected as an astable multivibrator set to run at about 43Hz by the resistors and capacitor connected to pins 6 & 7. Its pulse train output at pin 3 is high for 23ms and low for 70µs.

Pin 3 of IC1 controls IC2, a 4053 triple 2-channel demultiplexer. In our circuit we are using the 4053 as a 2-pole switch, with IC2a closed when IC2b is open, and vice versa. IC2a is used to alternately shunt the base current to the transistor under test, while IC2b is the sample-and-hold switch.

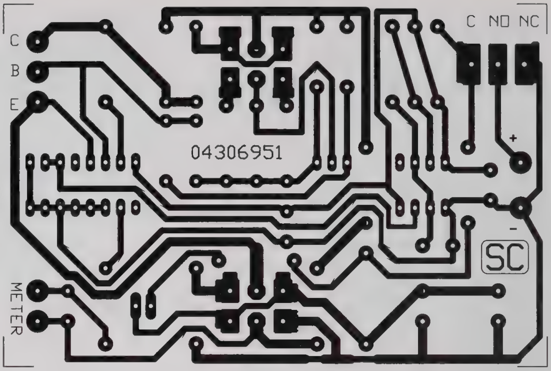
A crucial part of the circuit is the 2-pole toggle switch, S3. S3a & and S3b reverse the supply polarity to the tran-

Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	330kΩ	orange orange yellow brown	orange orange black orange brown
☐	1	6.8kΩ	blue grey red brown	blue grey black brown brown
☐	2	1kΩ	brown black red brown	brown black black brown brown
☐	1	120Ω	brown red brown brown	brown red black black brown
☐	2	100Ω	brown black brown brown	brown black black black brown
☐	1	68Ω	blue grey black brown	blue grey black gold brown
☐	1	47Ω	yellow violet black brown	yellow violet black gold brown
☐	1	1Ω	brown black gold gold	brown black black silver brown



The banana plugs are mounted close to the end of the case & with a spacing of 19.5mm. Alternatively, set them at the spacing to match your multimeter. Fig.7 at right shows the full-size etching pattern for the PC board.



sistor under test so that NPN and PNP devices can be tested. Since REF1, an LM334Z constant current source which supplies the base current, is a polarised device, a bridge rectifier consisting of diodes D1-D4 ensures that it is correctly polarised, regardless of whether NPN or PNP devices are being tested.

REF1 has its constant current programmed by the resistance connected between its R and V- pins. This is varied using 2-pole 3-position toggle switch S2. This is actually a "2-position, centre-off" switch which is connected to vary both the base current and the collector load resistor for the device under test.

Position 1 of S2a connects a 68Ω resistor in parallel with a 6.8kΩ resistor to provide a 1mA base current to the transistor under test. In position 2, the "centre-off" position, the 68kΩ resistor by itself sets the base current to 10μA.

Positions 1 and 3 of S2b switch a 1Ω resistor in parallel with 100Ω, while the "centre off" position 2 leaves the 100Ω resistor by itself. Hence, for power transistors and small signal Darlingtons, the collector load resistor is 1Ω (shunted by 100Ω) while for small signal transistors the collector load is 100Ω.

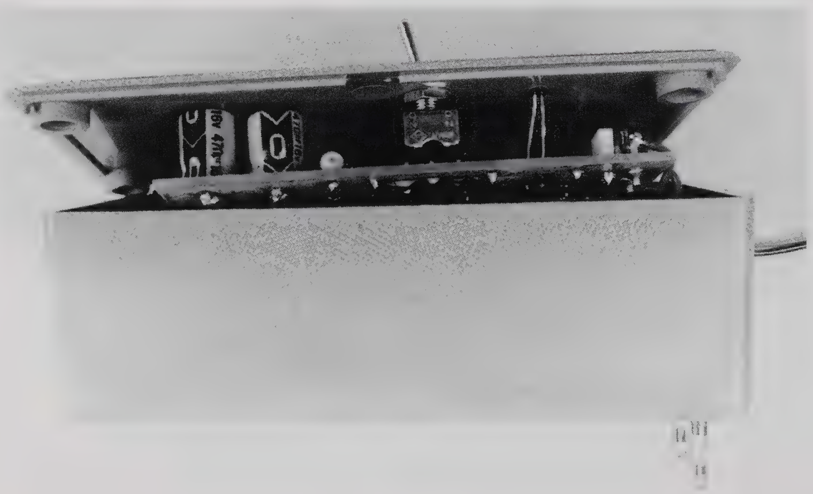
Power for the circuit is derived from a 9V battery which is applied via pushbutton S1 to S3 via a 120Ω resistor. This supply is decoupled with two parallel 470μF capacitors which provide the peak currents required.

When S1 is open, the supply rail is discharged using the normally closed contact to prevent any voltage remaining on the circuit when the switch is released. When the switch is pressed, the 470μF capacitors are initially discharged and so LED1 lights momentarily. This provides a good indication of battery condition at the beginning of each test.

Construction

The Beta Tester is housed in a plastic utility case measuring 130 x 67 x 43mm. All the circuitry mounts on a PC board coded 04306951 and measuring 92 x 61mm. This is secured to the lid by the three switches.

You can begin the construction by inserting PC stakes at the external wiring points. This done, install the resistors, links and diodes, followed by the capacitors and lastly, the integrated circuits. Make sure that the semiconductors and electrolytic capacitors are correctly polarised.



The PC board is attached to the lid of the case and held in place by the nuts of the switches. Note that the LED lead length needs to be adjusted so that the lens of the LED just protrudes from the front panel.

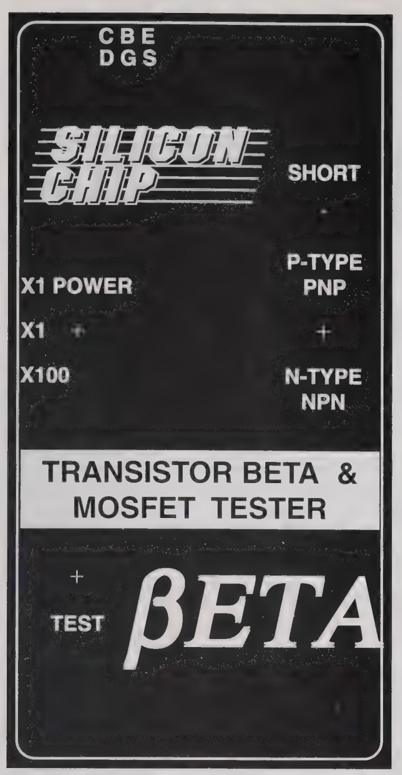


Fig.8: this full-size front-panel artwork for the Transistor Beta & Mosfet Tester can be used as a drilling template for the case lid.

Next, the switches can be installed. Note that pushbutton switch S1 must be oriented in a particular way. You will find that its three contacts are labelled C (common), NO (normally open; ie, when not pressed) and NC (normally closed). The contact positions should match the labelling on the copper pattern side of the board (ie, NC contact toward the edge of the board). Use the centre-off switch for S2.

Finally, LED1 is inserted so that it sits at the same height as the switch bushes. Do not cut its leads to length yet, so that it can be set to the correct height in the front panel later on.

Initial tests

Attach the battery clip leads to the PC board and apply power. Connect a multimeter between the negative battery lead and pin 8 of IC1 and check that there is about +8V present when S1 is pressed. Similarly, check for a similar voltage on pin 16 of IC2. Short the E and C terminals and with S2 in the x1 power position check that LED1 lights.

Now affix the label to the front panel and drill the holes for switches S1-S3 and LED1. The four corner holes in the lid should also be drilled out. One end of the case requires separate holes for the three test leads which are fitted with crocodile clips.

Drill 3mm holes for the banana plugs so that they are mounted as close to the end of the case as possible, 19.5mm apart. The battery can be held in place with a metal clamp or with Velcro®.

You will need to remove the internal ribs of the case so there is sufficient clearance for the PC board. You can do this job easily with a sharp chisel.

Now connect up wires on the board for the base, emitter and collector test leads and for the banana plugs. Attach the PC board to the front panel by firstly placing a single nut on each switch bush about 5mm down from the top and then securing the panel with a second nut on each switch bush. The LED should be adjusted in height so that it sits correctly in the front panel hole.

Attach the meter output wires to the banana plugs and pass the B, C and E wires through the holes in the case. Terminate these wires to the alligator or easyhook clips. Fit the lid assembly into the case, attach the screws and the tester is ready for service.

Measurements

Fig.6 shows typical pin-outs for various case styles of transistor. Use this to help with identifying the correct pin arrangement. When testing small signal transistors, use the x1 and x100 small signal setting for S2.

There will be some differences between readings on each range for a given device under test. This is because transistor gain varies with base current.

Mosfet "gain" values should be in the region of 1000 or more and should be tested on the x1 power position. The gate will only be pulled to about +6.5V due to the voltage drop across REF1 and the bridge rectifier which is usually not sufficient to turn a Mosfet fully on. Consequently, the Mosfet will be operating in the linear region.

Note that the polarity indication on the multimeter will differ, depending on the setting of the NPN/PNP switch (S3). **SC**

Parts List

1 PC board, code 04306951, 92 x 61mm
1 plastic case, 130 x 67 x 43mm
1 front panel label, 64 x 124mm
1 9V 216 battery & battery clip
1 SPDT momentary pushbutton PC board mounting switch (S1)
1 DPDT centre-off PC mount toggle switch (S2)
1 DPDT PC-mount toggle switch (S3)
7 PC stakes
2 banana plugs
2 3mm x 10mm screws & nuts
3 crocodile clips
1 50mm length of green hookup wire
1 50mm length of red hookup wire
1 100mm length of black hookup wire
1 100mm length of blue hookup wire
1 100mm length of yellow hookup wire
1 100mm length of 0.8mm diameter enamelled copper wire

Semiconductors
1 7555, TLC555CN or LMC555CN timer (IC1)
1 4053 triple 2-channel demultiplexer (IC2)
1 LM334Z current source (REF1)
4 1N4148, 1N914 signal diodes (D1-D4)
1 3mm red LED (LED1)

Capacitors
2 470μF 16VW PC electrolytic
2 10μF 16VW PC electrolytic
2 0.1μF MKT polyester

Resistors (0.25W 1%)
1 330kΩ
1 6.8kΩ
2 1kΩ
1 120Ω 1W
2 100Ω
1 68Ω
1 47Ω
1 1Ω

Universal power supply board for op amp circuits

There's more than one way to skin a cat and the same applies to designing a power supply. This small PC board enables you to obtain +15V, -15V or ±15V DC from several different transformer and rectifier combinations.

By LEO SIMPSON

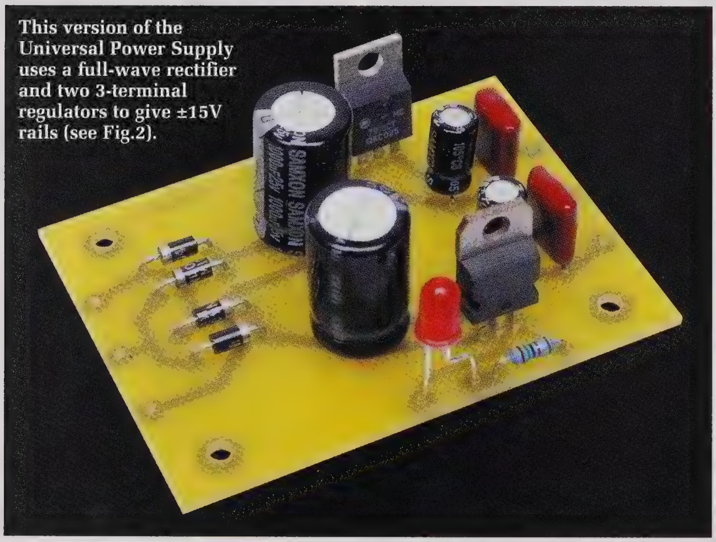
IT'S A PROBLEM that has confronted us on a number of occasions over the years; many circuits require ±15V DC rails or one or the other and, in each case, a suitable PC board has to be designed. Eventually, we decided to solve this problem for a number of different transformer combinations by coming up with a single universal PC board design.

One common situation is when you are powering a circuit from a 12VAC plugpack transformer but you want ±15V rails, using 3-terminal regulators. Sounds difficult? Nope, piece of cake. Just use two half wave rectifiers to obtain the positive and negative rails and then follow with the regulators.

Or maybe you have a more conventional situation with a 12VAC transformer such as the Ferguson PF2851 (or equivalent). To obtain ±15V DC the circuit is the same. But if you have a 30VAC centre-tapped transformer such as the one from Altronics (Cat. M-2855), you then use a bridge rectifier, followed by the filter capacitors and 3-terminal regulators.

Anyway, you get the general idea. We are presenting one PC board pattern and showing how to use it in four different ways, depending on what your requirements are and what transformer you are using. Actually, there are other options and we'll mention those later.

The board measures 71 x 52mm (code 04106881) and was used for the first time in the Studio 200 Stereo Control Unit, part two of which is featured elsewhere in this issue. We'll be using it again in a few months' time.


This version of the Universal Power Supply uses a full-wave rectifier and two 3-terminal regulators to give ±15V rails (see Fig.2).

The circuit variations

Fig.1 shows the first circuit situation presented above and could be used with a 12VAC plugpack or with any chassis mounting transformer with an output voltage or 12-15V AC. You can regard the circuit in two ways. First, as two half-wave rectifiers, D1 and D2, producing filtered but unregulated DC supply rails of ±18-22V, depending on the transformer secondary voltage.

The other way of regarding the circuit of Fig.1 is as a conventional half-wave voltage doubler circuit which has been "centre-tapped" at the junction of the two 1000µF capacitors. Either way, the result is the same.

Because D1 and D2 function as half-wave rectifiers, the ripple voltage superimposed on the DC supplies will be 50Hz. This may or may not be a problem but, for a given current drain from the supplies, the ripple voltage will be slightly more than twice the 100Hz ripple obtained if the bridge rectifier circuit of Fig.2 is used.

Fig.2 may be used with a 30V centre-tap M-2855 transformer from Altronics, Jaycar, or with any similar 24V or 30V centre-tap transformer. Following the bridge rectifier diodes, the unregulated DC voltage will be again be ±18-22V, depending on the transformer.

The 3-terminal regulators to be used will normally be 7815 or LM340T-15 (or other variants) for the +15V supply. For the negative rail, the equivalent types are 7915 or LM320T-15 (or other variants). The output side of the

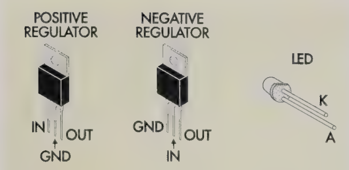

POSITIVE REGULATOR
NEGATIVE REGULATOR
LED
IN
OUT
GND
GND
OUT
IN
K
A

Fig.5: here are the pinouts for the 3-terminal regulators and the LED.

regulators have 100µF and 0.1µF capacitors connected to ensure good transient response and stability. We also made provision for a LED (light emitting diode) power indicator fed via a resistor from the positive supply.

Single supply versions

Fig.3 is a single supply version of the board using a 30V centre-tap (CT) or 24V CT transformer. Here, D1 and D2 provide full wave rectification and the resulting ripple is 100Hz. The unregulated DC voltage will be between +18V and +22V.

Fig.4 is a single supply circuit using a 12V or 15V transformer feeding a bridge rectifier. Again, the unregulated DC voltage will be between +18V and +22V, with ripple at 100Hz.

All the circuits presented here are good for several hundred milliamps but those which use full wave rectification will naturally be able to extract more current from the given transformer.

If you want more current, a bigger transformer will be required and the regulator(s) will have to be fitted with heatsink(s). It is also a good idea to go for bigger filter capacitors; ie, 2200µF or 2500µF, instead of the 1000µF units shown on the circuits.

Less than 15V supplies

Want less than 15V? No problem, you can install 12V regulators instead although for a given current drain their dissipation will be slightly higher.

You can also go for 5V or 8V regulators if you wish although then it would be wise to reduce the transformer secondary voltage from 30V CT to 15V CT for Fig.2 and to around 6-7V for Fig.1.

The LED current limiting resistor can be 1.5kΩ for +12 or +15V outputs, reduced to 680Ω for 8V outputs and to 470Ω for 5V outputs. The LED can be omitted, of course, in which case the limiting resistor can be left out too.

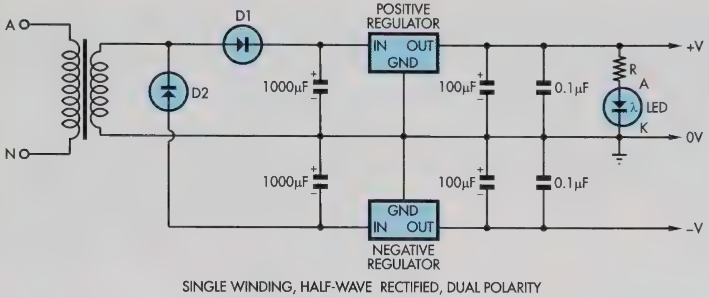

A
N
D1
D2
POSITIVE REGULATOR
IN OUT GND
1000µF
1000µF
100µF
100µF
0.1µF
0.1µF
R
A
LED
K
+V
0V
–V
GND IN OUT
NEGATIVE REGULATOR
SINGLE WINDING, HALF-WAVE RECTIFIED, DUAL POLARITY

Fig.1: this dual polarity version uses a 12-15V transformer to drive half-wave rectifiers (D1 and D2) and two 3-terminal regulators.

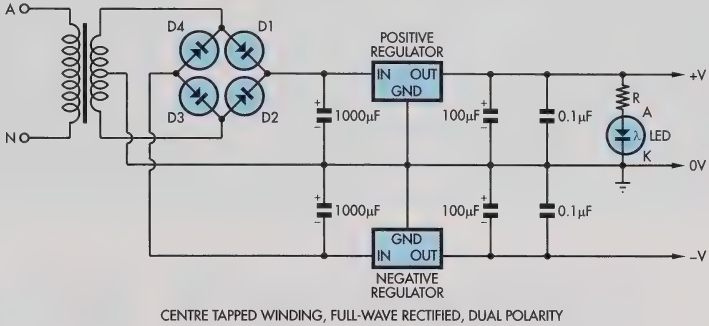

A
N
D4
D1
D3
D2
POSITIVE REGULATOR
IN OUT GND
1000µF
1000µF
100µF
100µF
0.1µF
0.1µF
R
A
LED
K
+V
0V
–V
GND IN OUT
NEGATIVE REGULATOR
CENTRE TAPPED WINDING, FULL-WAVE RECTIFIED, DUAL POLARITY

Fig.2: in this circuit, a centre tapped transformer and bridge rectifier are used to drive the 3-terminal regulators.

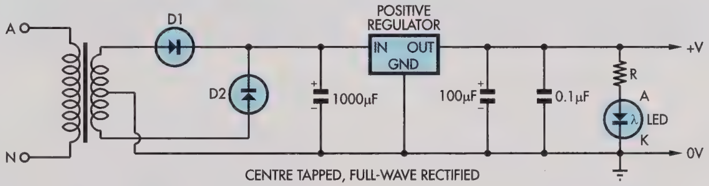

A
N
D1
D2
POSITIVE REGULATOR
IN OUT GND
1000µF
100µF
0.1µF
R
A
LED
K
+V
0V
CENTRE TAPPED, FULL-WAVE RECTIFIED

Fig.3: this single supply circuit uses D1 and D2 to provide full wave rectification from a centre-tapped transformer.

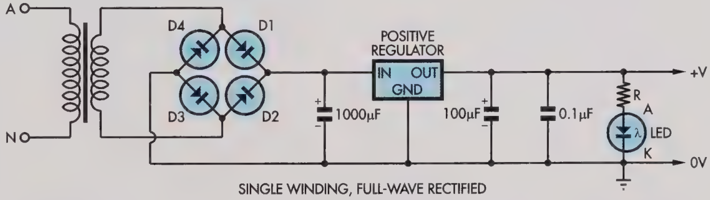

A
N
D4
D1
D3
D2
POSITIVE REGULATOR
IN OUT GND
1000µF
100µF
0.1µF
R
A
LED
K
+V
0V
SINGLE WINDING, FULL-WAVE RECTIFIED

Fig.4: single supply version using a 12-15V transformer and a bridge rectifier. The unregulated DC voltage will be between 18-22V.

Other variants

You can also produce a single (positive) supply version of Fig.1 if you wish, by leaving out D2, the negative 3-terminal regulator and the three associated capacitors. Or, if you want a negative supply version, leave out D1, the positive 3-terminal regulator and its three associated capacitors.

By now, you'll have the general idea

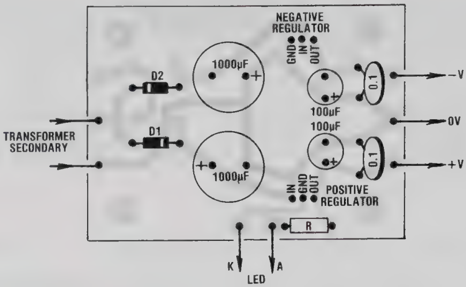

NEGATIVE REGULATOR
GND
IN
OUT
1000µF
D2
D1
TRANSFORMER SECONDARY
100µF
100µF
0.1
0.1
−V
0V
+V
1000µF
IN
GND
OUT
POSITIVE REGULATOR
R
K
A
LED

Fig.6: parts layout diagram for the circuit shown in Fig.1. The value of R depends on the supply rail (see text).

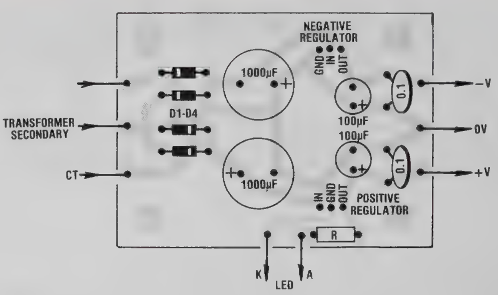

NEGATIVE REGULATOR
GND
IN
OUT
1000µF
D1-D4
TRANSFORMER SECONDARY
CT
100µF
100µF
0.1
0.1
−V
0V
+V
1000µF
IN
GND
OUT
POSITIVE REGULATOR
R
K
A
LED

Fig.7: this parts layout diagram corresponds to the circuit shown in Fig.2. Take care with component polarity.

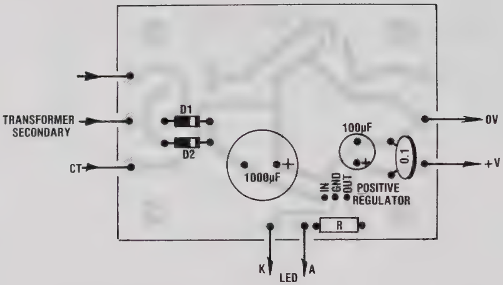

TRANSFORMER SECONDARY
CT
D1
D2
1000µF
100µF
0.1
0V
+V
IN
GND
OUT
POSITIVE REGULATOR
R
K
A
LED

Fig.8: parts layout the single supply version shown in Fig.3. A centre-tapped transformer must be used.

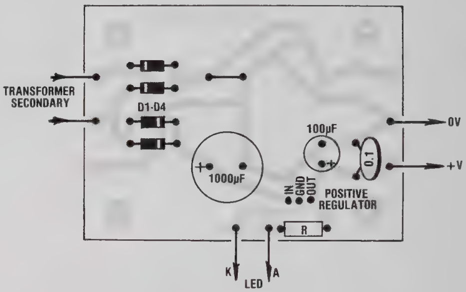

TRANSFORMER SECONDARY
D1-D4
1000µF
100µF
0.1
0V
+V
IN
GND
OUT
POSITIVE REGULATOR
R
K
A
LED

Fig.9: parts layout for the circuit shown in Fig.4. Don't forget to install the wire link.

Parts List

±15V Supply (see Fig.1)

1 PC board, code 04106881, 71 x 52mm
1 2851 power transformer with 12.6V secondary
2 1N4002 silicon diodes
1 7815 3-terminal regulator
1 7915 3-terminal regulator
2 1000µF 25VW PC-mount electrolytic capacitors
2 100µF 25VW PC-mount electrolytic capacitors
2 0.1µF metallised polyester capacitors (greencaps)
1 red LED
1 1.5kΩ 0.25W resistor

Alternative ±15V Supply (See Fig.2)

1 PC board, code 04106881, 71 x 52mm
1 M-2855 power transformer
4 1N4002 silicon diodes
1 7815 3-terminal regulator
1 7915 3-terminal regulator
2 1000µF 25VW PC-mount electrolytic capacitors
2 100µF 25VW PC-mount electrolytic capacitors
2 0.1µF metallised polyester capacitors (greencaps)
1 red LED
1 1.5kΩ 0.25W resistor

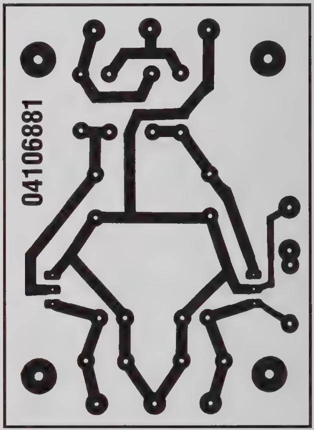


Fig.10: check your PC board against this full-size etching pattern

and will see that a number of other variations are possible, with grounded positive or negative rails, or fully floating outputs. It's up to you.

Wiring them up

We have shown four wiring diagrams for the circuits depicted in Figs.1-4. There are only two particular wrinkles to watch out for when wiring up these boards. First, watch out for the polarity of diodes and capacitors. Second, note that the pinouts for the positive and negative regulators are not the same.

For positive regulators, the centre pin is GND (ground or 0V). For negative regulators, the centre pin is the input (IN). If you get these connections wrong, you'll blow the regulators. **SC**

TELEPHONE LINE SIMULATOR

This 2-line Telephone Exchange Simulator can be used to test telephone handsets, fax machines, modems, answering machines and other telephone equipment such as diallers on burglar alarms. It contains the all the circuitry necessary to accept decadic (pulse) or DTMF (tone) dialling.

Telephone Exchange Simulator For Testing

Have you ever wanted to test the modem section on a piece of electronic equipment but were unable to afford the luxury of a small PABX? Or are you in the production side of electronics and need to simulate a telephone exchange to test the finished product? Well, this Telephone Exchange Simulator can overcome these problems.

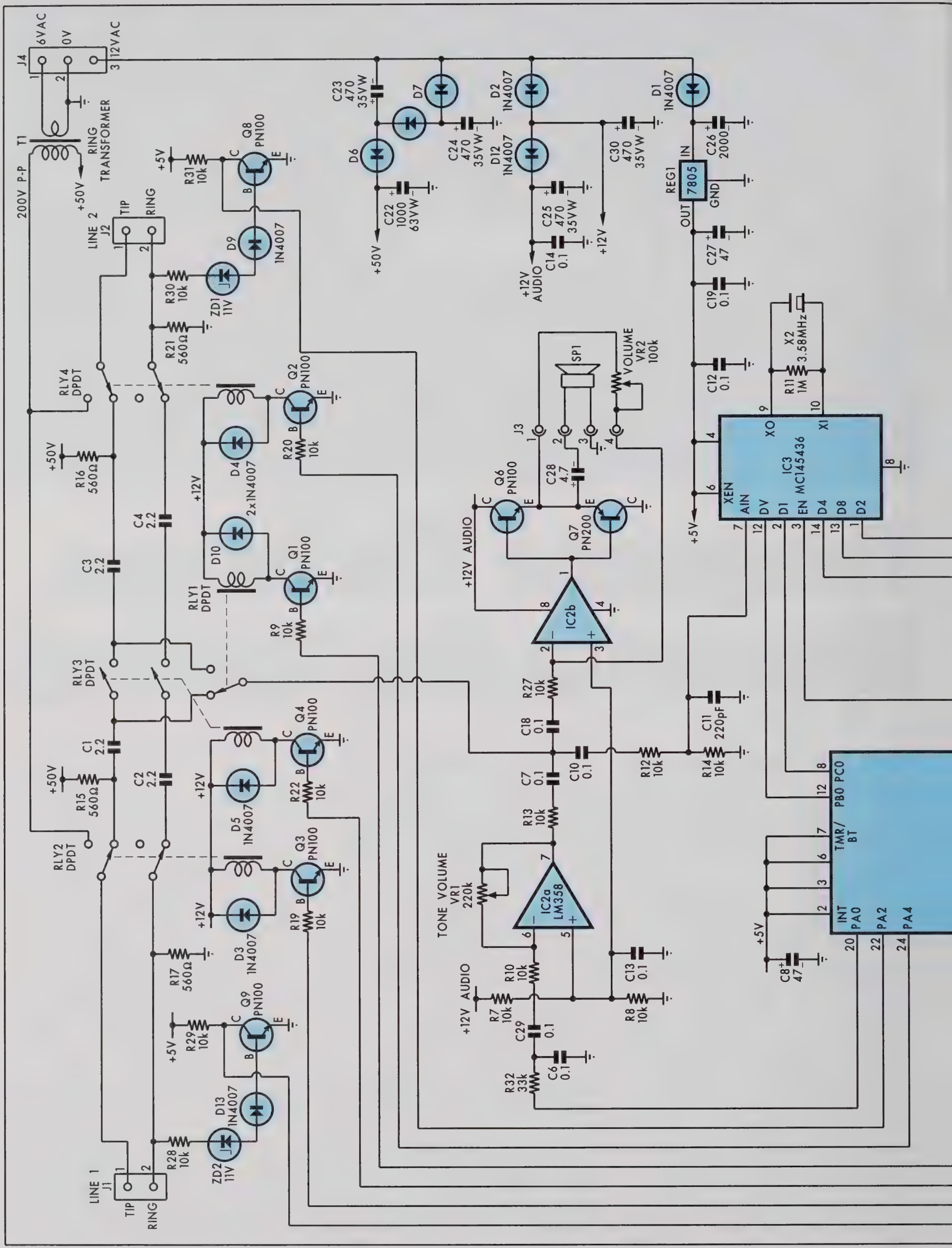
By MIKE ZENERE

Testing faulty or new pieces of telephone equipment over the switched network is illegal and can incur large fines if you are detected. Best not to do it. What you really need is a test box which can automatically detect decadic or tone dialling and can display the progress of a call via LEDs on the front panel. The unit to be described can also be an interface between your fax machine and PC, enabling you to scan in documents or pictures.

Modems and faxes present a real problem if you want to test them. Say you have a fully approved and working modem or fax and you want to test it out. Sure, you can legally test them over the phone lines but you need two phone lines to do it and that's not always easy. It might be easy enough if you have two lines coming into your residence but if yours is a commercial organisation, getting access to telephone lines which are already connected to your PABX is not convenient or legal either. So this Telephone Exchange Simulator fills a real need.

The Telephone Exchange Simulator is housed in a plastic instrument case and has a telephone socket on each side. You can connect two telephone handsets and place a call between them, in either direction. The phones can use either decadic (ie, pulse) or tone (DTMF) dialling and the unit will automatically detect either mode.

In the following example, a telephone will be used to illustrate the call procedure but it could be any sort of appliance that might use the public switched telephone network (PSTN).


J4
6VAC
0V
12VAC
T1
RING TRANSFORMER
200V P-P
+50V
LINE 2
J2
TIP
RING
+5V
R31 10k
Q8 PN100
D9 1N4007
R30 10k
ZD1 11V
R21 560Ω
RLY4 DPDT
Q2 PN100
R20 10k
D4 2x1N4007
D10
Q1 PN100
R9 10k
RLY1 DPDT
+12V
R16 560Ω
C4 2.2
C3 2.2
RLY3 DPDT
C1 2.2
C2 2.2
R15 560Ω
RLY2 DPDT
Q4 PN100
R22 10k
D5 1N4007
Q3 PN100
R19 10k
D3 1N4007
R17 560Ω
Q9 PN100
R29 10k
D13 1N4007
R28 10k
ZD2 11V
LINE 1
J1
C23 470 35VW
D7
D6
C22 1000 63VW
C24 470 35VW
D2 1N4007
D12 1N4007
C25 470 35VW
C14 0.1
+12V AUDIO
C30 470 35VW
D1 1N4007
C26 2000
REG1 7805
IN
OUT
GND
C27 47
C19 0.1
C12 0.1
X2 3.58MHz
R11 1M
SP1
VOLUME VR2 100k
J3
C28 4.7
Q6 PN100
Q7 PN200
IC2b
R27 10k
C18 0.1
C10 0.1
R12 10k
C11 220pF
R14 10k
C7 0.1
R13 10k
TONE VOLUME VR1 220k
IC2a LM358
R10 10k
R7 10k
C29 0.1
C6 0.1
R32 33k
C13 0.1
R8 10k
IC3 MC145436
XO
XI
XEN
AIN
DV
D1
EN
D4
D8
D2
PB0 PC0
TMR/ BT
INT PA0
PA2
PA4
C8 47

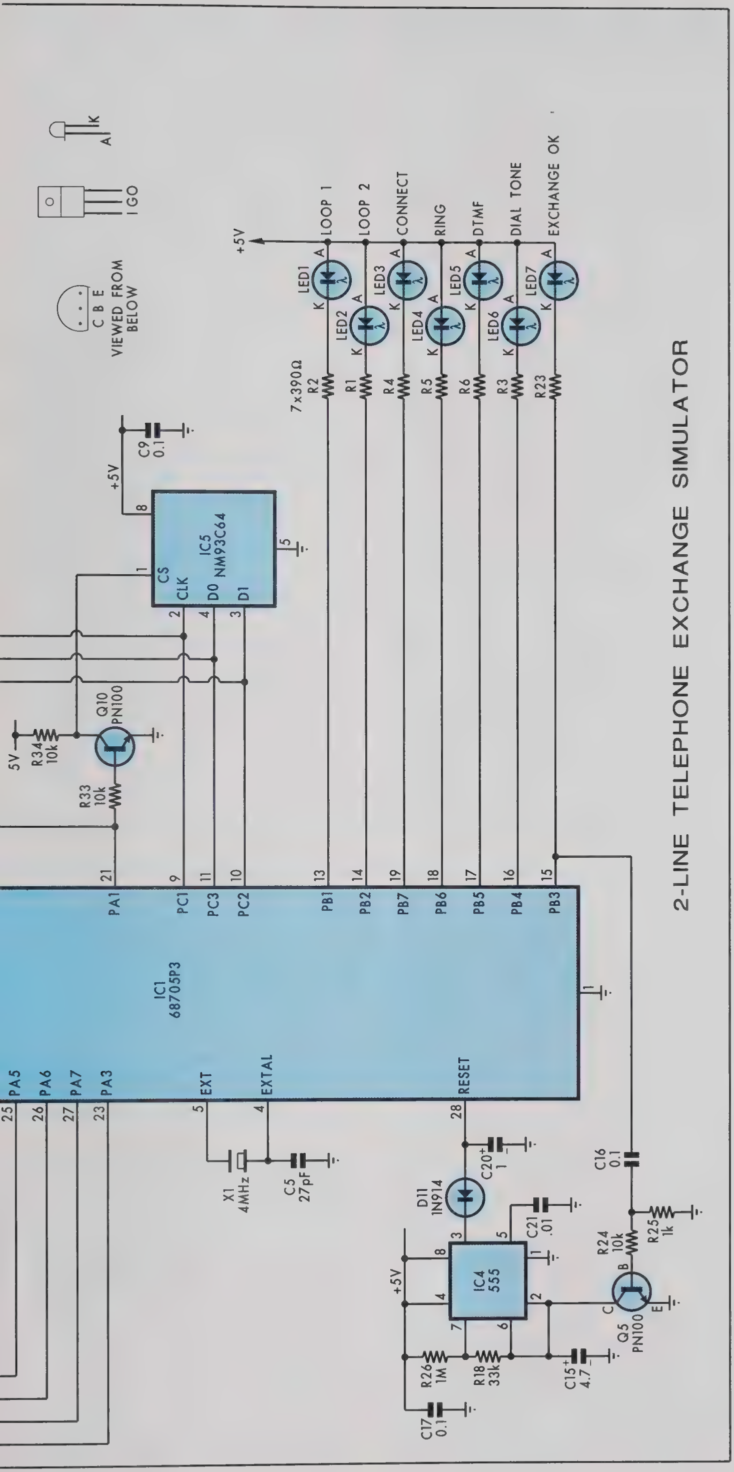

2-LINE TELEPHONE EXCHANGE SIMULATOR
IC1 68705P3
IC4 555
IC5 NM93C64
LOOP 1
LOOP 2
CONNECT
RING
DTMF
DIAL TONE
EXCHANGE OK
7x390Ω
VIEWED FROM BELOW
C B E
I G O
A K
+5V
Q10 PN100
Q5 PN100
D11 1N914
X1 4MHz
C5 27pF
C9 0.1
C16 0.1
C15 4.7
C17 0.1
C20 1
C21 .01
R24 10k
R25 1k
R26 1M
R18 33k
R33 10k
R34 10k
PA1
PA3
PA5
PA6
PA7
PB1
PB2
PB3
PB4
PB5
PB6
PB7
PC1
PC2
PC3
EXT
EXTAL
RESET
CS
CLK
D0
D1

Fig.1 (left): the heart of the circuit is the 68705P3 processor which controls all the phone functions apart from DTMF decoding which is done by IC3.

A call is made in this way: lift the handset of one telephone and listen for dial tone. At this point both the LOOP LED and the DIAL TONE LED should be on, signifying that a call is in progress. Also an audible sound should be heard from the internal speaker. Start dialling, noticing that the dial tone disappears and either the DTMF LED or the LOOP LED are flashing, in accordance with the digits dialled. If the exchange receives a correct number, ring tone will be heard in both the speaker and the ear piece as well as an audible ringing of the phone.

If the called phone is answered, the second LOOP LED and the CONNECT LED will light, showing that the call is connected. A speech path is now formed from one telephone to the other.

This simple test procedure will not only enable you to test typical telephone handsets but it is also very useful for testing cordless phones. And as already noted, it will let you test fax machines and modems and answering machines too.

Some useful terminology

Listed below are some terms that may be useful:

On hook: the telephone receiver is on the phone and the phone is disconnected from the line.

Off hook: the telephone receiver is off the phone and the phone is connected to the line.

Dial tone: the sound you hear when you first pick up the receiver before you start dialling.

Ring tone: the sound you hear when the exchange is calling the other end.

Busy tone: the sound you hear when you have called the other end but their phone is in use.

No progress tone: the sound you hear when the wrong number has been dialled.

How it works

Fig.1 shows the complete circuit of the Telephone Exchange Simulator.

At the heart of the circuit is IC1, a 68705P3 single chip microcontroller. This device is a complete computer on a chip and controls the entire exchange simulator.

This device is somewhat old now but as they are in plentiful supply and fulfil the requirements of this project, they were used. A review of the functions of the 68705P3 was featured in the September 1992 issue of SILICON CHIP.

Another key feature of the circuit is the two Line Loop Detectors, comprising zener diode ZD1, diode D9 and transistor Q8 for the first detector and ZD2, D13 and Q9 for the second detector.

Line loop detectors

Line loop detectors are the curse of the telephone exchange designer and at first glance these two line loop detectors may appear to be quite simple but the amount of design time and testing that went into this part of the circuit was enormous. In fact, more time was spent getting this part of the circuit to work properly than was spent on the rest of the project, including writing the article.

The line loop detectors are used to sense a low resistance loop in the line; eg, someone has lifted a handset.

It was decided that a loop current of 20-25mA minimum would be required to cause the Simulator to accept that a call was being made. Looking at the line one circuit, we can see that the basic telephone circuit is made up of +50V, resistor R15, RLY2 contacts, the telephone handset itself, RLY2 contacts, resistor R17 and ground. With the telephone on-hook, the line appears as an open circuit to the exchange and as such, no voltage is developed across R17.

When the telephone handset is lifted, a low resistance loop is placed across the TIP and RING of socket J1 and as current flows through the loop, a DC voltage is developed across resistor R17. Just how much voltage depends on the type of telephone, modem or whatever is making the call. But in any case, we need to produce around 12V across R17 to get our 20-25mA flowing through the circuit.

When the voltage across R17 reaches or rises above this level, the loop detector comes into play. Zener diode ZD2 conducts via diode D13 and feeds current into the base of transistor Q9 to turn it on. This pulls pin 23 of IC1 low, which signals to the processor that a call is under way.

Where To Buy A Kit

A complete kit of parts for the Telephone Exchange Simulator is available from the author who owns the design copyright. This kit includes all components, including the programmed microprocessor, PC board, transformers and case

Further information is available from Mike Zenere, phone (03) 9806 0110.

"So what's so hard about loop detection?" you may ask. Well not much at this point but let's go to the other end where after the correct number has been dialled by the calling end, bursts of 50Hz ring current are fed out to the called telephone.

The exchange is now in calling mode and is sending bursts of 50Hz at 200V peak-to-peak imposed on 50V DC at one instant and then in the next, is sending 50V DC to line. This means that at any time the called end answers the call, the telephone may be seeing anything between +150V to -50V in the ring cycle or straight 50V DC. In any case we want the exchange to answer the call within a short time and to turn off the ring current.

To help with the explanation, let's divide this up a bit.

Case 1: Relay RLY4 is not operated as we are between ring bursts, thus we are sending 50V DC to line. The circuit path is now +50V, R16, RLY4 contacts, the telephone, RLY4 contacts, resistor R21 and ground (ie, 0V).

No current flows in the loop until the telephone is answered at which point more than 12V appears across resistor R21. This causes zener diode ZD1 to conduct via diode D9, causing base current to flow into transistor Q8 which now turns on. This pulls pin 22 of IC1 low; the processor is now signalled.

Case 2: Relay RLY4 is operated as we are sending ring current to the line. The circuit path is now +50V, ring transformer T1, RLY4 contacts, the telephone, RLY4 contacts, resistor R21 and ground.

Remember, at this point the telephone is unanswered but a capacitor in the phone passes the AC to the bells or ringer and causes voltage fluctuations across resistor R21. These may well be enough to turn on the line loop detector if the voltage rises above +12V, causing the exchange to think the phone has been answered.

This is where the problem lies, as how can the exchange tell if the call is being answered or it is being tricked by the ring current? The answer lies in the software.

Let's assume that the capacitor in the phone is quite large and is causing a 50Hz AC signal to appear at the line loop detector. This in turn is causing a signal to be sent to the processor. Anything above 12V will cause the line loop detector to be on and anything below 12V will cause it to be off.

As the 50Hz AC ring signal is symmetrical, the line loop detector will be on for less time than it is off. How can this be? Well, a complete cycle takes 20ms so each peak is active for 10ms. This would normally send a square wave to the processor but as we need to reach +12V before the loop detector operates, the signal to the processor now has a longer on time than off time. When the call is answered, the line is biased positive by the +50V rail on one side of transformer T1.

This has the effect of lifting the line DC potential and causing the line loop detectors to be more on than off. The signal to the processor now has a longer off time than on time. During the calling cycle the processor is doing what we will call a data acquisition on its associated line loop detector port pin.

In this case, line two's line loop detector is being read by the software at 800 times a second and a record is kept of its on and off times. This information is sent through a subroutine in software and if the conditions are right the call is deemed to be answered.

Power supplies

The Telephone Exchange Simulator requires five different supply rails to work properly and these are derived mainly from a 12V AC transformer. The different sections are described below.

The logic side of the board draws around 150mA and its 5V rail is derived from the 12V secondary winding using a half-wave rectifier D1 and a 2000µF filter capacitor C26. This feeds 3-terminal 5V regulator REG1.

There are two 12V supplies one of which powers the audio section of the circuit involving dual op amp IC2 while the other 12V rail powers the relays. Separating the relay circuitry from the op amp section helps reduce noise and distortion.

The first 12V source is derived via diode D2 and capacitor C30, while the second 12V rail source is derived from diode D1 and capacitors C25 and C14.

+50V supply

Three diodes, D6, D7 & D8 and three capacitors C22, C23 & C24 make up a voltage tripler from the 12VAC and this produces around 50VDC. This voltage is used to drive the telephone handsets and provide our speech path to the other end.

200V supply

The voltage to ring a standard issue Telstra phone is quite high and considering a customer could be over 4km from the exchange a voltage of 200V peak-to-peak (70V RMS) is required. The simplest way to provide this is to use a step-up transformer fed from 6VAC.

Notice that one side of the output winding is tied to +50V DC so that if the called end is answered in the middle of a ring burst, the simulator will stop sending ring current in a very short period. The two line relays RLY2, and RLY4 were needed to totally isolate the high voltage from the rest of the circuit.

Watchdog circuitry

The watchdog circuitry is used to prevent the processor from "locking up" and thereby causing the unit to become inoperative. This circuit employs a 555 timer IC4 which is used in an astable mode to reset the processor. If allowed, IC4 would oscillate at a frequency of about 0.25Hz, as set by the values of R18, R26 and C15.

When the processor is running properly, it toggles its EXCHANGE OK port pin every second or so which temporarily turns on transistor Q5 and discharges C15.

While C15 is unable to charge via R18 and R26, the output of the 555 timer stays high, thus allowing the processor to continue normal opera-

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NORM
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One of the side-benefits to the deregulation of the Australian telephone industry is increased access to installation, service and maintenance work for approved personnel. However, the availability of suitable equipment has sometimes been a problem.

A Brisbane company, Telephone Technical Services, recognised the need for a range of high-quality telephone and line test equipment and is now importing the US-made "Test-Um Inc" range.

Of particular interest are the phone test sets (called "butt phones") which offer a broad range of testing facilities. There are two in the range, the "Lil' Buttie" LB100 and the "Lil' Buttie Pro" LB200.

The big difference between the two is an LCD panel on the Pro model which reveals even more information about the line under test, including on-hook voltage, off-hook current, the number dialled, stored numbers, setup and call waiting information and even caller ID information.

Other equipment in the Test-Um range includes the TG100 tone generator, the TT100 tone tracer, the TP100 "Tell-All" tester for both phone and data lines, and similar devices.

For further information contact Telephone Technical Services on (07) 3286 6388, fax (07) 3286 6399, or visit their website at www.ttservices.com.au (see advert page 55).

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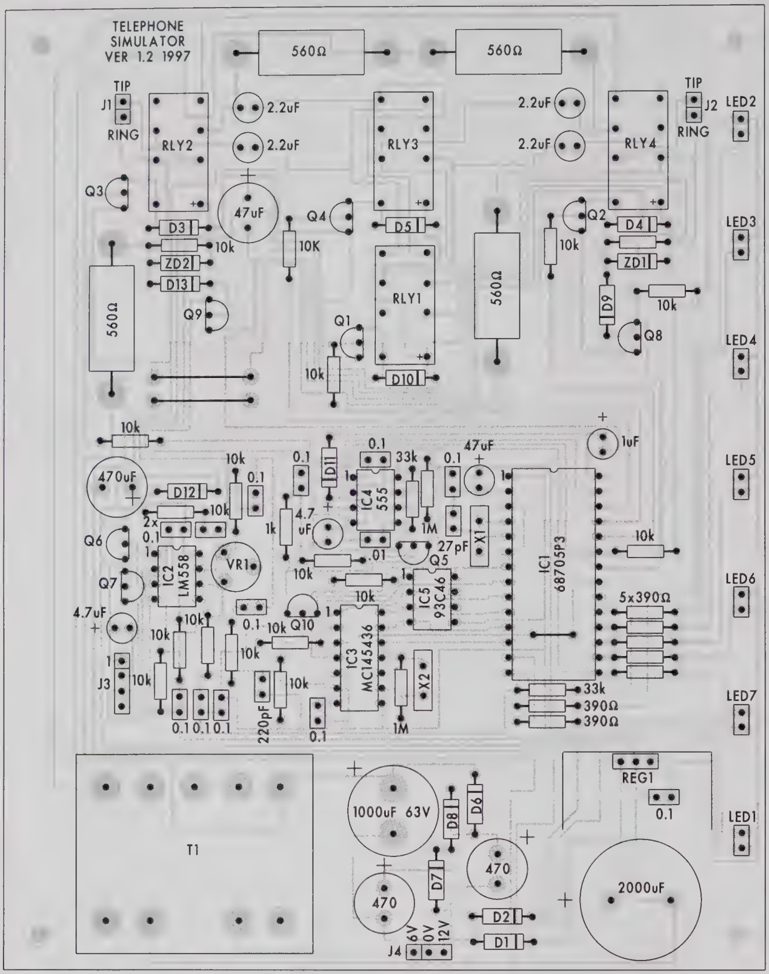

TELEPHONE
SIMULATOR
VER 1.2 1997
560Ω
560Ω
TIP
J1
RING
RLY2
2.2uF
2.2uF
RLY3
2.2uF
2.2uF
RLY4
TIP
J2
RING
LED2
Q3
47uF
Q4
D3
10k
10K
ZD2
D13
D5
RLY1
560Ω
10k
Q2
D4
ZD1
D9
10k
Q8
LED3
560Ω
Q9
Q1
10k
D10
LED4
10k
1uF
470uF
10k
0.1
D11
0.1
33k
0.1
47uF
D12
IC4
555
10k
2x 0.1
4.7 uF
1k
1M
X1
IC1
68705P3
10k
LED5
Q6
IC2
LM558
VR1
.01
27pF
Q5
10k
IC5
93C46
10k
LED6
Q7
5x390Ω
4.7uF
10k
0.1
10k
Q10
10k
IC3
MC145436
J3
10k
10k
220pF
10k
X2
33k
390Ω
390Ω
LED7
0.1 0.1 0.1
0.1
1M
REG1
0.1
T1
1000uF 63V
D8
D6
LED1
470
D7
470
2000uF
D2
6V 0V 12V
J4
D1

Fig.2: the component layout of the PC board. The LEDs are bent at rightangles to protrude through the front panel.

tion. However, if the program were to lock up, Q5 would remain off and allow C15 to charge, thus switching pin 3 of the 555 low.

The reset line of the processor would now be pulled low via diode D11 and is held low until the 555 changes state. At this point the processor starts again and continues pulsing its port pin.

Audio monitoring

When testing equipment, it is useful to hear what is being sent from the calling end or even from one caller to another. With DTMF dialling, tones are sent from the telephone to the exchange and are decoded by a special chip. If you suspect your telephone or modem is not sending DTMF you will be able to pick it up.

Capacitor C18 is used to provide DC isolation between op amp IC2b and the external telephone circuit. When an AC signal appears (due to DTMF, tones or voice) across C18 they are amplified by IC2b. This op amp drives a complementary output stage consisting of transistors Q6 & Q7 and these drive the loudspeaker via coupling capacitor C28.

Relay driver

Under normal conditions the processor's port pins are low, thereby leaving the relay driver transistors in the off state. When the processor wishes to enable a relay its associated port pin goes high and causes base current to flow to the transistor which turns on to operate the relay. The diode across each relay coil prevents any spikes from damaging the associated transistor when it turns off.

Tone injector

When making a call, certain tones are sent to the calling end to inform the user as to what's happening; eg, ring tone, busy tone or no progress tone (wrong number). The tones are injected in the following way. One port pin is used to try and reproduce all of the tones required. This process comes pretty close to doing what we want.

IC2a is configured as an amplifier with its gain set by VR1 and R10. The signal waveform from the processor is rounded off by R32 and C6 and is then coupled by C29 to the op amp which amplifies it and sends it out to the line via R13 and C7.

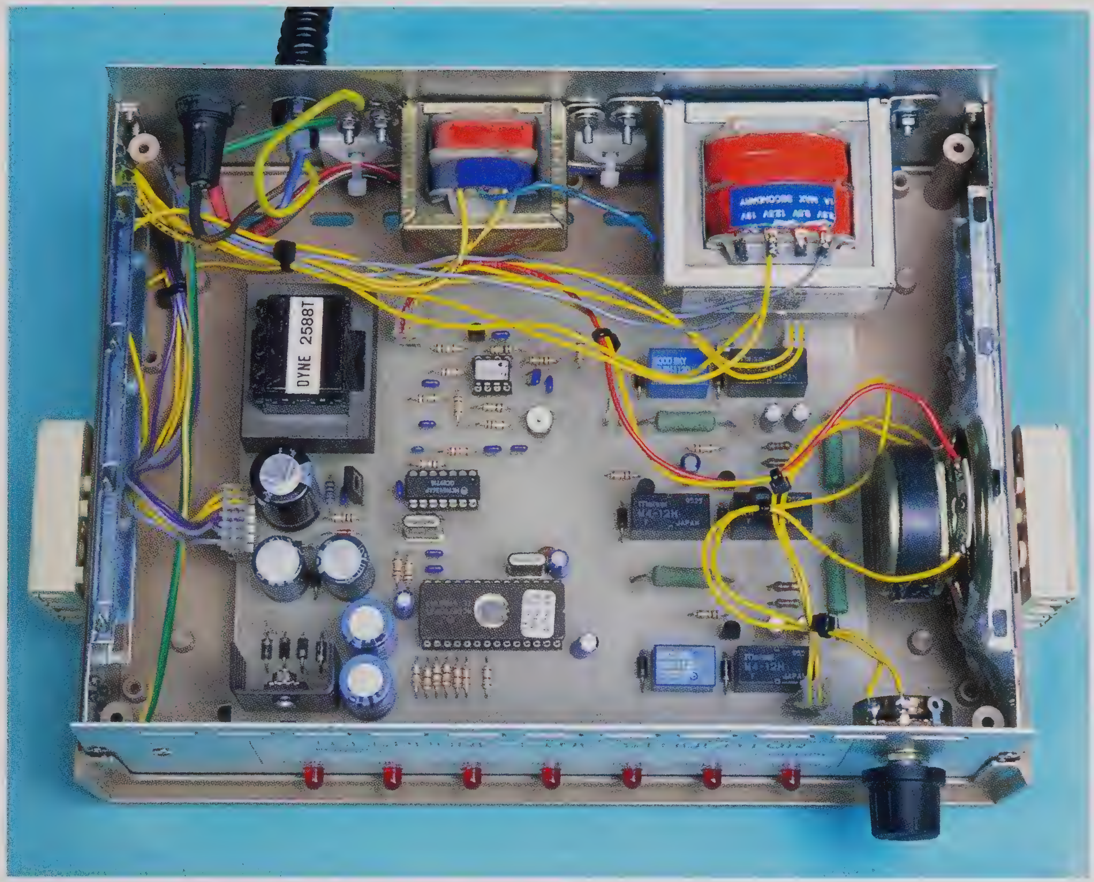
DTMF detection

DTMF (dual tone multi frequency) detection is done using IC3, a Motorola MC14-5436 tone decoder which receives the incoming tones via a filter network comprising resistors R12 & R14 and capacitor C11. When a valid tone is detected, the DV line (pin 12) of IC3 goes high, signalling to the processor that a digit is being pushed. At this point the processor enables the decoder's output pins by taking the EN line high (pin 3) and reads in the data.

Assembly procedure

Most of the circuitry of the Telephone Exchange Simulator is accommodated on a PC board measuring 161 x 128mm. The components off the board are the power transformer and speaker.

By the way, the prototype shown in the photos has undergone a number of fairly substantial changes so the assembly notes apply only to the cir-



Inside the Telephone Exchange Simulator. Note that the PC board and wiring layout of the prototype pictured here has been fairly significantly modified in the final PC board depicted in Fig.2.

cuit of Fig.1 and the PC component layout of Fig.2. Note also that the prototype photos show two power transformers inside the rear panel but the final version uses just one power transformer.

You can begin the PC board assembly by mounting the four standoffs, one on each corner of the board. Next, all of the resistors, links relays, diodes and capacitors can be soldered in. Screw the 7805 regulator to the heatsink with the screw, washer and nut provided and solder this into place.

The remainder of the components, with the exception of the ICs can now be mounted. This done, mount the two telephone sockets and transformer and glue the speaker onto the side of the case with some silastic.

You will need to drill holes for the mains fuse and cordgrip grommet for the mains power cord. The mains wiring can be run, taking care to insulate with heatshrink any exposed terminals.

Don't forget to attach the earth wire to a solder lug separately bolted to the case rear panel. An earth wire should also be run from this point to a solder lug securely bolted to the front panel. If necessary, scrape away any anodising to ensure a good contact with the metalwork.

Now temporarily connect up the sockets, speaker and transformer with longer pieces of wire to enable you to test the board out of the case.

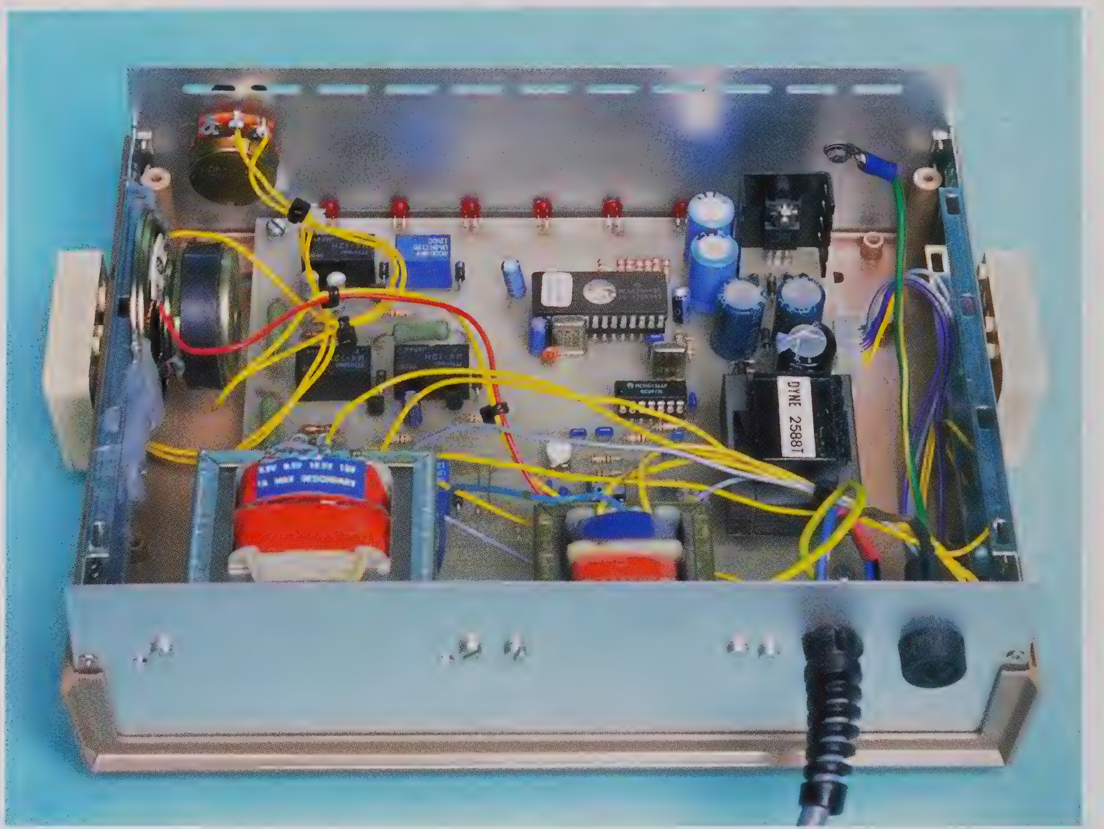
Testing

Before proceeding, it is well to note that although the ring transformer (T1) looks fairly insignificant, it puts out quite a bite if you get caught across its output. I certainly found this out the hard way!

Without any ICs plugged in, turn on the power and check voltages around the board, especially the supply rails to the processor. If all is OK, turn off the power and plug in the ICs. Turn on the power again and use a small screwdriver to short out the TIP and RING connectors of each telephone line in turn. Each time you do so, the LOOP LED for that line should come on.

Plug a phone in at each end and lift one of the receivers. Listen for dial tone and use trimpot VR1 to set the tone to the desired level. If the tone level is too high, you may swamp the DTMF from the phone, causing the Exchange to miss any dialled digits.

Also at this time use the volume control (VR2) on the front panel to set



Use cable ties to neatly secure the wiring and insulate the terminals of the fuseholder with heatshrink tubing, to prevent accidental contact with the mains. Be sure to earth both the front and rear panels of the case (see text).

the volume coming out of the speaker. With the receiver off hook, hit some of the keys on the telephone and listen for tones through the speaker. If all seems well, you can shorten the wires and solder them to the posts. If you have connectors that are spaced at 0.1 inch you can use these instead of hard wiring.

Storing a telephone number

As this is a two-line telephone exchange simulator we need a telephone number for each end. These are stored in the serially fed EEPROM, IC5.

Pick up one end and wait for dial tone. Hit *6805 and wait for two beeps before dialling in your telephone number of up to 20 digits in length. When this is done, hit the # button to terminate and wait for two beeps. You have now programmed that extension with its own number. Do the same for the other end and yes, you are allowed to have the same number at both ends.

Detailed talk-through

For this procedure we'll assume a phone is plugged in at each end.

Lift the handset for line one. This causes a voltage of more than 12V to appear across the line loop detectors, thus signalling the processor.

The exchange now realises that you want to make a call so it switches RLY1 over and starts injecting dial tone out through its port pin, through IC2a where it is amplified, through RLY1, through C1 and out to the line.

At the same time, the tone is also fed to op amp IC2b via C18 and R27 where it is amplified and buffered by transistors Q6 & Q7. This audio is now heard through the speaker. The user starts dialling and the tones are passed by C1 back through RLY1, through C10 and the filter network to the DTMF decoder, IC3.

Once a tone pair has been recognised, DV (pin 12) on the MC145436 goes high, signalling to the processor to get the data in. The digit is retrieved and stored until the whole number is complete or until it gets a wrong digit, at which time the "No progress" tone is sent back to the caller.

Once the correct number has been loaded, the exchange starts toggling RLY4, causing bursts of ring current to be fed out to line. Also ring tone is sent back to the user to indicate what is happening. If the second phone is answered, the line loop detector signals to the processor to stop sending ring current and RLY4 remains in its normal state.

The ring tone is stopped and RLY3 operates, causing a speech path to be established. The call is now complete. During the progress of the call the LEDs on the front panel will be operating to indicate the progress. **SC**

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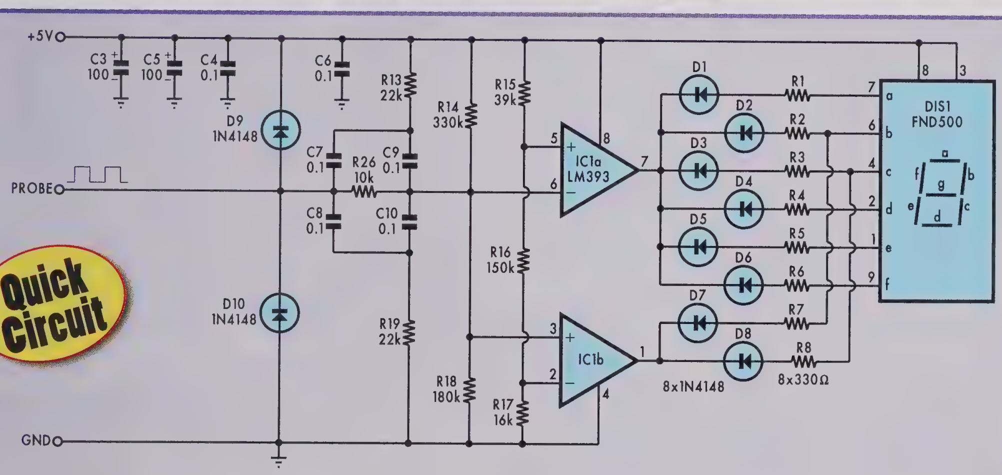

+5V
C3 100
C5 100
C4 0.1
C6 0.1
R13 22k
R14 330k
R15 39k
D9 1N4148
PROBE
C7 0.1
R26 10k
C9 0.1
C8 0.1
C10 0.1
IC1a LM393
R16 150k
D10 1N4148
R19 22k
IC1b
R18 180k
R17 16k
GND
D1
D2
D3
D4
D5
D6
D7
D8
8x1N4148
R1
R2
R3
R4
R5
R6
R7
R8
8x330Ω
DIS1 FND500
a
b
c
d
e
f
g

Quick Circuit

Logic probe with 7-segment LED display

This logic probe uses a 7-segment display to show logic states rather than the conventional approach of using LEDs. The display shows "1" for a high logic state and "0" for a low. This can be useful when troubleshooting 8-bit decoding circuits.

The circuit uses an LM393 dual comparator set up as a "window" comparator. The switching thresholds of the two comparators are set by the three-resistor divider connected to pins 5 & 2 while the input signal is connected via a 10kΩ resistor to pins 6 & 3.

D9 & D10 provide input protection while C7-C10 provide filtering to prevent false triggering.

When the input signal is high, IC1a's output goes low to turn on segments a, b, c, d, e & f, via diodes D1-D6. If the input signal is low, IC1b's output goes low to turn on segments b & c via diodes D7 & D8.

Note that the circuit is only suitable for CMOS logic operating at 5V.

T. Jackson.

Measure resistance up to 2200 gigohms!

High-Voltage Insulation Tester

This high-voltage insulation tester can measure resistance from 1-2200 gigohms. It is battery powered and displays the readout on a 10-step LED bargraph display.

By JOHN CLARKE

In all cases, when ever mains-operated equipment has been built or repaired, it is wise to test the insulation resistance between active and neutral to earth. This will verify that there is no leakage path to earth which could lead to a serious breakdown later on or pose a hazard to the user if the earth connection fails.

Of course, a multimeter set to the high ohms range can often detect insulation problems but this is not always a valid test. That's because a multimeter only produces a very low value test voltage (around 1.5V) and many types of insulation breakdown occur at much higher voltages.

Another problem with a normal multimeter is that it will only show overrange for "good" insulation measurements rather than the actual value of the resistance. This is because insulation resistance measurements usually result in readings of thousands of megohms (ie, gigohms – GΩ) rather than the nominal 20MΩ maximum value for a multimeter.

The Insulation Tester described here is a self-contained meter which will measure very high values of leakage resistance for a number of test voltages. It will also test capacitors for leakage. A 10-LED bargraph display is used to indicate the leakage resistance. A test voltage switch selects between five possible values, while a 3-position range switch selects either x1, x10 or x100 scale readings.

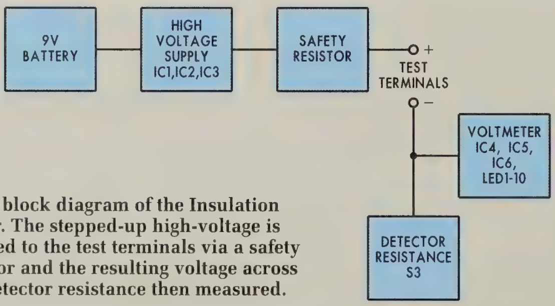

9V BATTERY
HIGH VOLTAGE SUPPLY IC1,IC2,IC3
SAFETY RESISTOR
+
TEST TERMINALS
–
VOLTMETER IC4, IC5, IC6, LED1-10
DETECTOR RESISTANCE S3

Fig.1: block diagram of the Insulation Tester. The stepped-up high-voltage is applied to the test terminals via a safety resistor and the resulting voltage across the detector resistance then measured.

Block diagram

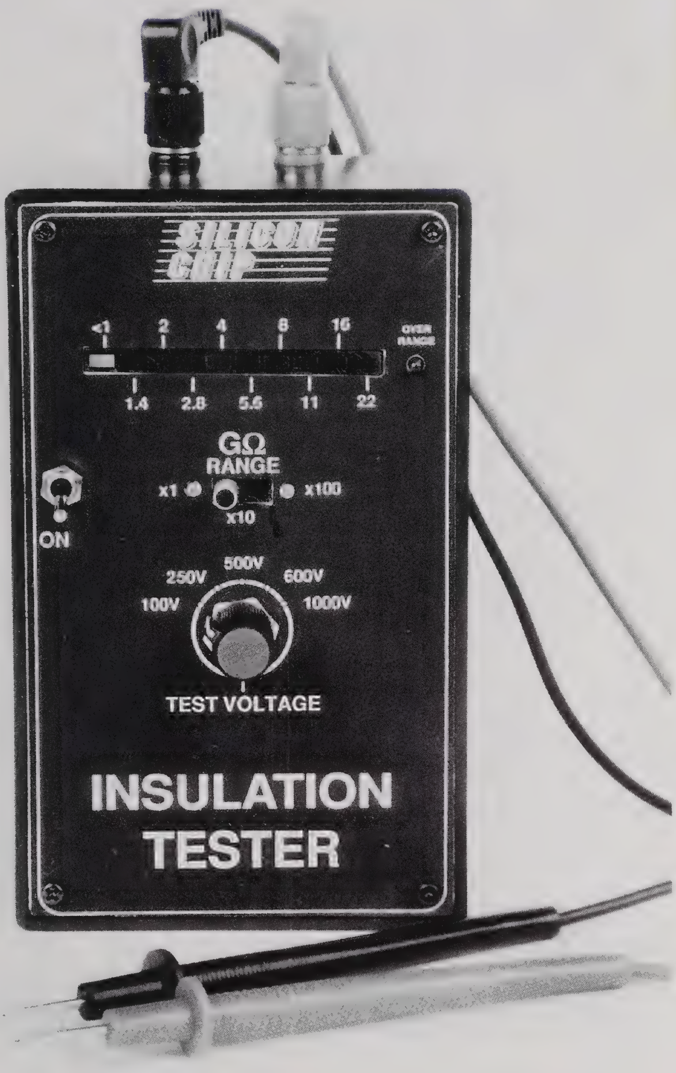
Fig.1 shows the block diagram of the Insulation Tester. It is based on a high voltage supply, produced by stepping up from a 9V battery using a converter. This converter can produce either 100V, 250V, 500V, 600V or 1000V DC.

Note that, because of the high voltages involved, a safety resistor is included in series with the output. This limits the output current to a minuscule level to (a) protect the circuit when the probes are short circuit; and (b) prevent the user from receiving a nasty electric shock.

In operation, the leakage of the insulation under test causes a current to flow between the test terminals. This current is then monitored by the detector resistance between the negative test terminal to ground. The higher the leakage current, the higher the voltage across the detector resistance.

This voltage is measured using a special voltmeter circuit which is calibrated to show the resistance on a LED bargraph readout. This is no ordinary meter since it cannot divert any significant current away from the detector resistance or false readings will occur. And the currents involved are extremely minute.

A simple calculation will tell us exactly how small the currents flow-



The prototype Insulation Tester was built into a standard plastic case. Be sure to use good-quality test leads, as cheaper types will show significant leakage at high test voltages.

Features

- LED bargraph display
- Five test voltages from 100-1000V
- Measures from 1GΩ (1000MΩ) to 2200GΩ (2.2TΩ)
- Battery operated
- Overrange indication

ing between the test terminals are. Assuming a 1000V test voltage and a 2000MΩ (2GΩ) resistance between the test terminals, the current flow will be just 1000/(2 x 10^9) = 500nA. The same resistance at a test voltage of 100V will allow only 50nA to flow.

At 2200GΩ (the upper measurement limit of the Insulation Tester), the current flow is a minuscule 45pA (45 x 10^{-12}) when 100V is applied. As a consequence, we need to measure the voltage across the detector resistor without drawing any more than a few picoamps (pA).

Circuit details

Fig.2 shows the full circuit of the Insulation Tester. It uses six ICs, a transformer, Mosfet Q1 and a number of minor components.

The step-up converter uses the two windings of transformer T1 to produce up to 1000VDC. When Mosfet transistor (Q1) is switched on, it charges the primary winding via the 9V supply. When Q1 is switched off, the charge is transferred to the secondary and delivered to a .0033μF 3kV capacitor via series diodes D1-D3. These three diodes are rated at 500V each and so together provide more than the required 1000V breakdown.

Following the .0033μF capacitor, the stepped-up voltage is filtered using a 4.7MΩ resistor and a 470pF capacitor. It is then fed to the positive test terminal via a second 4.7MΩ resistor. Note that these two 4.7MΩ resistors provide the current limiting function referred to earlier.

Q1 is driven by an oscillator formed by 7555 timer IC2. This operates by successively charging and discharging a .0039μF timing capacitor (on pins 2 & 6) via a 6.8kΩ resistor connected to the output (pin 3). Let's take a closer look at how this works.

When power is first applied, the capacitor is discharged and the pin 3 output is high. The timing capacitor then charges to the threshold voltage at pin 6, at which point pin 3 switches low and the capacitor discharges to the lower threshold voltage at pin 2. Pin 3 then switches high again and so this process is repeated indefinitely while ever power is applied.

The voltage at the output of the converter is controlled by monitoring

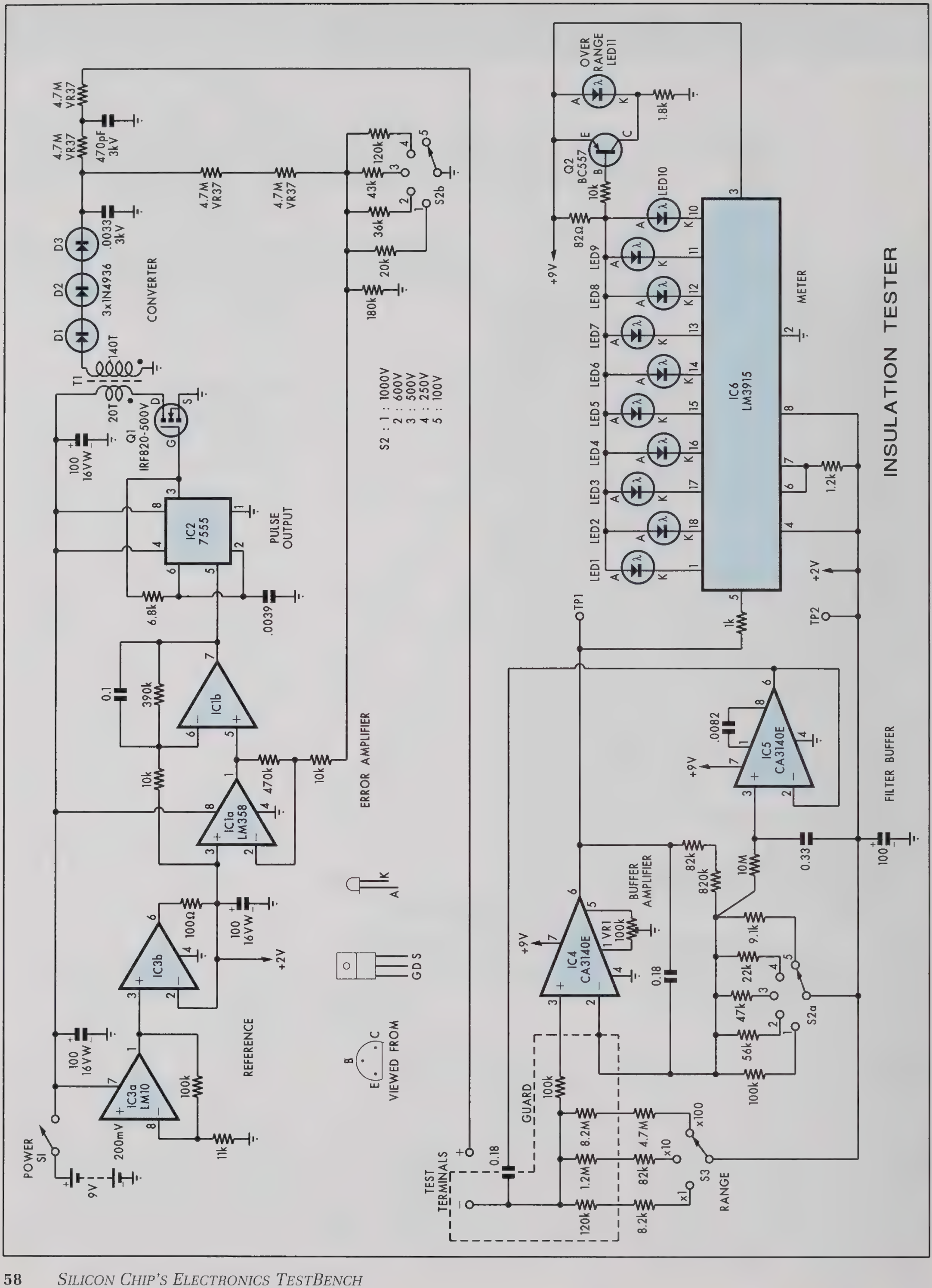

INSULATION TESTER
POWER S1
9V
200mV
IC3a LM10
100k
11k
100 16VW
REFERENCE
IC3b
100Ω
100 16VW
+2V
IC1a LM358
10k
470k
10k
ERROR AMPLIFIER
IC1b
390k
0.1
6.8k
.0039
IC2 7555
PULSE OUTPUT
Q1 IRF820-500V
100 16VW
T1
20T
140T
D1
D2
D3
3x1N4936
CONVERTER
.0033 3kV
4.7M VR37
470pF 3kV
4.7M VR37
4.7M VR37
4.7M VR37
180k
20k
36k
43k
120k
S2b
S2 : 1 : 1000V
2 : 600V
3 : 500V
4 : 250V
5 : 100V
G D S
E B C
VIEWED FROM
A K
TEST TERMINALS
GUARD
0.18
100k
120k
1.2M
8.2M
8.2k
82k
4.7M
x1
x10
x100
S3
RANGE
IC4 CA3140E
BUFFER AMPLIFIER
1 VR1 100k
+9V
0.18
100k
56k
47k
22k
9.1k
S2a
82k
820k
10M
0.33
100
FILTER BUFFER
IC5 CA3140E
.0082
+9V
TP1
TP2
1k
+2V
IC6 LM3915
METER
1.2k
LED1
LED2
LED3
LED4
LED5
LED6
LED7
LED8
LED9
LED10
82Ω
+9V
10k
Q2 BC557
OVER RANGE LED11
1.8k

Fig.2: the circuit uses a step-up converter based on IC1a, IC1b, IC2 and Q1 to produce test voltages ranging from 100-1000V.

Parts List

- 1 PC board, code 04303961, 86 x 133mm
- 1 adhesive label, 90 x 151mm
- 1 plastic case with metal lid, 158 x 95 x 52mm
- 1 SPDT toggle switch (S1)
- 1 2-pole 6-position rotary PC board mounting switch (S2)
- 1 2-pole 3-position slider switch plus screws (S3)
- 1 red banana panel mount socket
- 1 black banana panel mount socket
- 1 test lead set (see text)
- 1 9V battery
- 1 battery holder and mounting screws
- 1 EFD20 transformer assembly (Philips 2 x 4312 020 4108 1 cores, 1 x 4322 021 3522 1 former, 2 x 4322 021 3515 1 clips) (T1)
- 1 150mm length of red hookup wire
- 1 150mm length of black hookup wire
- 1 150mm length of yellow hookup wire
- 1 150mm length of green hookup wire
- 1 400mm length of mains-rated wire
- 1 7-metre length of 0.25mm ENCW
- 1 80mm length of 0.8mm tinned copper wire
- 1 20mm knob
- 4 small stick-on rubber feet
- 13 PC stakes
- 1 100kΩ horizontal trimpot (VR1)

Semiconductors

- 1 LM358 dual op amp (IC1)
- 1 7555, TLC555, LMC555CN CMOS timer (IC2)
- 1 LM10CLN op amp and reference (IC3)
- 2 CA3140E Mosfet input op amps (IC4,IC5)
- 1 LM3915 log bargraph driver (IC6)
- 1 IRF820, BUZ74 or BUK455-500A 500V N-channel Mosfet (Q1)
- 1 BC557 PNP transistor (Q2)
- 1 10-LED bargraph (LED1-LED10)
- 1 3mm red LED (LED11)
- 3 1N4936 fast recovery diodes (D1-D3)

Capacitors

- 4 100µF 16VW PC electrolytic
- 1 0.33µF MKT polyester
- 2 0.18µF MKT polyester
- 1 0.1µF MKT polyester
- 1 .0082µF MKT polyester
- 1 .0039µF MKT polyester
- 1 .0033µF 3kV ceramic
- 1 470pF 3kV ceramic

Resistors (0.25W 1%)

- 1 10MΩ
- 1 8.2MΩ
- 1 4.7MΩ
- 4 4.7MΩ Philips VR37
- 1 1.2MΩ
- 1 820kΩ
- 1 470kΩ
- 1 390kΩ
- 1 180kΩ
- 2 120kΩ
- 3 100kΩ
- 2 82kΩ
- 1 56kΩ
- 1 47kΩ
- 1 43kΩ
- 1 36kΩ
- 1 22kΩ
- 1 20kΩ
- 1 11kΩ
- 3 10kΩ
- 1 9.1kΩ
- 1 8.2kΩ
- 1 6.8kΩ
- 1 1.8kΩ
- 1 1.2kΩ
- 1 1kΩ
- 1 100Ω
- 1 82Ω

the voltage across a resistor selected by S2b and feeding this to an error amplifier. In greater detail, S2b selects one of five range-setting resistors. This, in conjunction with two associated 4.7MΩ resistors, forms a voltage divider across the converter output.

The voltage divider output is applied to error amplifier IC1a via a 10kΩ resistor. This stage is cascaded with IC1b for high gain. IC1b's output, in turn, drives the threshold pin (pin 5) of IC2.

If the output voltage goes too high, IC1b pulls pin 5 of IC2 slightly lower so that the pulse width duty cycle to Q1 is reduced. This in turn lowers the output voltage. Conversely, if the output voltage is too low, IC1b pulls pin 5 of IC2 higher. This then increases the duty cycle of the drive to Q1 and so the output voltage also increases.

Basically, IC1a compares the voltage divider output with a fixed reference voltage applied to its pin 3. This reference voltage is provided by IC3a and IC3b. IC3a is part of an LM10 dual op amp which includes a 200mV fixed reference at its non-inverting input (pin 3). It amplifies this reference by a factor of 10 to provide 2V at its pin 1 output.

IC3b is connected as a unity gain buffer and provides a low impedance output for the 2V reference. Note that the reference voltage is taken from the inverting input at pin 2, while the output at pin 6 drives pin 2 via a 100Ω resistor. This resistor isolates IC3b's output from the associated 100µF decoupling capacitor.

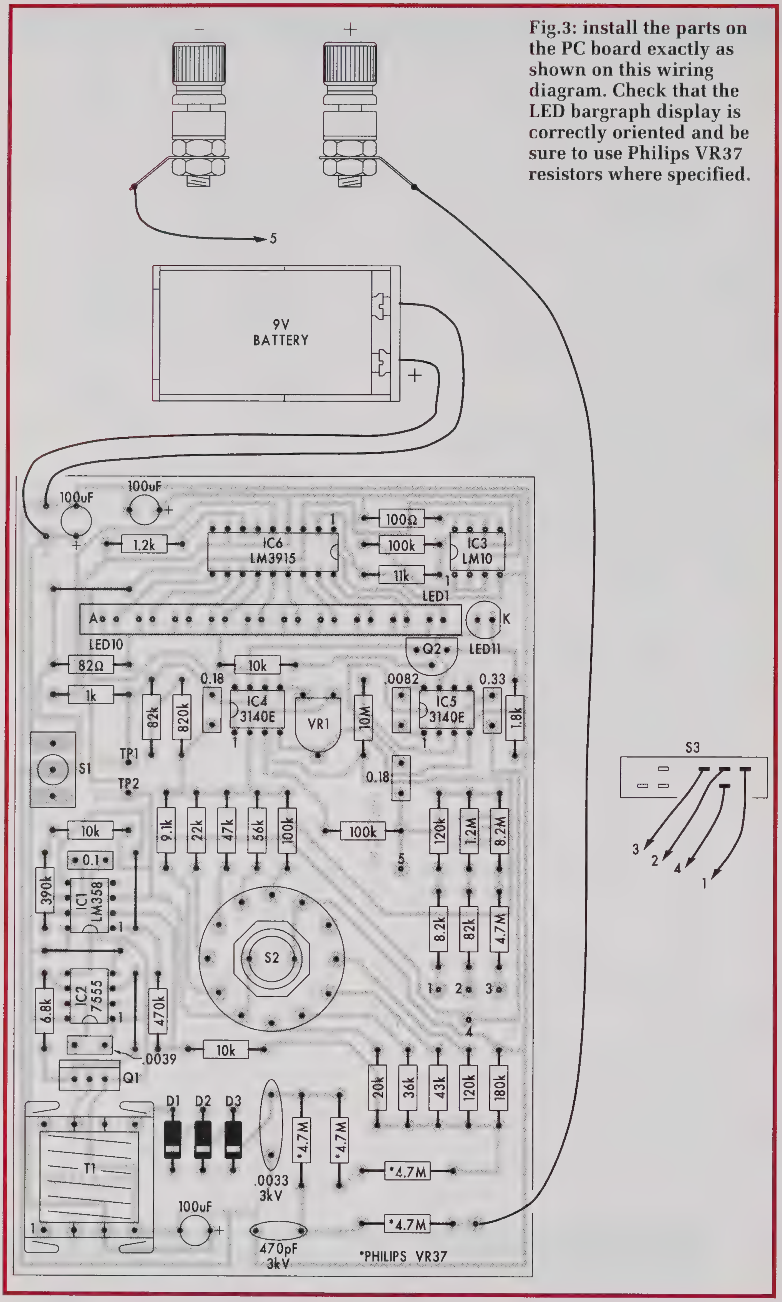
IC4, a CA3140E FET-input op amp, functions as a buffer stage and is used to monitor the voltage across the detector resistor. This op amp offers a very high input impedance of 1TΩ (1000GΩ) and a nominal 2pA input current at the 9V supply. However, this input impedance and current is only valid if there is no leakage on the PC board.

To prevent board leakage we have added a guard track around the input which is at the same voltage as pin 3. This effectively prevents current flow from the negative test terminal to other parts of the circuit.

Trimpot VR1 (between pins 1 & 5) is used to adjust the offset voltage at the output (pin 6) of IC4, while S2a sets the gain. This varies from x10 in the

Specifications

Test voltages	100, 250, 500, 600 & 1000V
Test voltage accuracy	<5%
Charging impedance	9.4MΩ
Current drain 50mA	@1000V out



-
+
5
9V BATTERY
+
100uF
100uF
1.2k
IC6 LM3915
1
100Ω
100k
IC3 LM10
11k
1
LED1
A
K
LED10
Q2
LED11
82Ω
10k
1k
82k
820k
0.18
IC4 3140E
1
VR1
10M
.0082
IC5 3140E
1
0.33
1.8k
TP1
S1
TP2
0.18
10k
9.1k
22k
47k
56k
100k
100k
5
120k
1.2M
8.2M
0.1
390k
IC1 LM358
1
S2
8.2k
82k
4.7M
1
2
3
6.8k
IC2 7555
1
470k
4
.0039
10k
Q1
D1
D2
D3
20k
36k
43k
120k
180k
T1
1
•4.7M
•4.7M
•4.7M
.0033 3kV
100uF
•4.7M
470pF 3kV
•PHILIPS VR37
S3
3
2
4
1

Fig.3: install the parts on the PC board exactly as shown on this wiring diagram. Check that the LED bargraph display is correctly oriented and be sure to use Philips VR37 resistors where specified.

1000V position up to x100 for the 100V setting. These gain adjustments are necessary to compensate for the voltage change that occurs across the detector resistance each time the test voltage is changed.

The 100kΩ input resistor at pin 3 of IC4 protects the input from damage if the test terminals are shorted, even at the 1000V setting.

Switch S3 selects one of three possible resistance values for the separate ranges. Position 1 selects a 128.2kΩ resistance (120kΩ + 8.2kΩ), position 2 selects 1.282MΩ and position 3 selects 12.82kΩ. These are unusual values but are necessary to correspond to a 1.28V full scale reading for the LED bargraph driver (IC6).

Because of the high impedance at the negative test terminal, the input is prone to hum pickup and so it is filtered using a 0.18μF capacitor. Note that the earthy side of this capacitor is connected to the output of IC5 rather than to ground or to the 2V rail. This arrangement ensures that there is no DC voltage across the capacitor, thus giving the filter a fast response time.

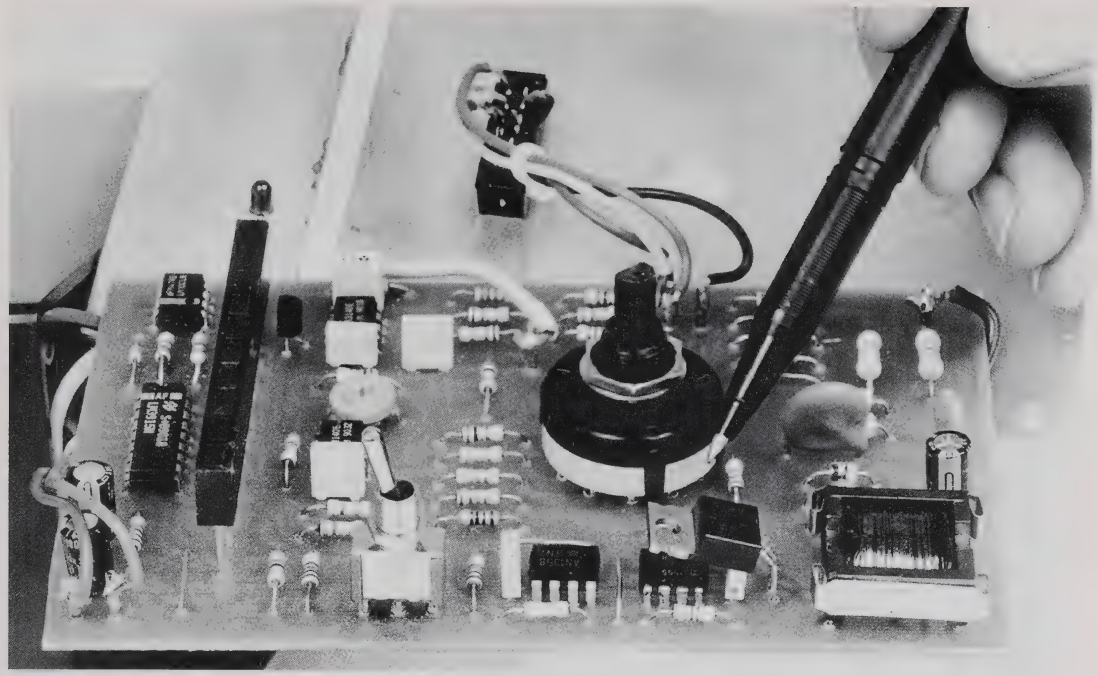
Conversely, if DC voltage had been allowed to appear across the capacitor, the circuit would have taken a considerable time to settle each time a measurement was taken.

Buffer stage IC5 (another CA3140) monitors IC4's pin 2 voltage via a 10MΩ resistor and a 0.33μF capacitor. The output from IC5 at pin 6 is thus a replica of the signal on pin 3 of IC4. It is connected to the earthy side of the 0.18μF filter capacitor, as mentioned above.

Note that IC5 has been given a slow response by connecting a .0082μF compensation capacitor between pins 1 and 8.

IC4's output is applied (via a 1kΩ resistor) to the pin 5 signal input of IC6. This is a logarithmic LED bargraph display driver which switches on LEDs 1-10 in the dot mode. Each step in the bargraph is 3dB (1.41) apart, giving a total 30dB range.

Note that the lower threshold (RLO – pin 4) of IC6 sits at the +2V reference level provided by IC3b. This means that the upper threshold (RHI – pin 6) sits at 3.28V, since this pin sits 1.28V above RLO as set by an internal regulator. This 1.28V



Bend Mosfet Q1 over as shown in this photograph, so that it doesn't foul the front panel. The LED bargraph (lefthand end) is installed so that its top surface is about 19mm above the PC board.

difference between RLO and RHI sets the maximum display sensitivity. The 1.2kΩ resistor on pin 7 sets the LED brightness.

Q2 and LED11 provide the overrange indication. If any of the LEDs is on, Q2 is biased on due to the current flowing through the 82Ω resistor. As a result, LED11 is off since Q2 effectively shorts it out.

Conversely, if all the LEDs are out (which equates to a very high resistance), Q2 is biased off and so LED11 now lights to indicate an overrange.

Power for the circuit is derived from a 9V battery via switch S1. There are several 100μF capacitors across the supply and these are used to decouple the 9V rail.

Construction

Most of the circuitry for the Insulation Tester is mounted on a PC board coded 04303961 and measuring 86 x 133mm.

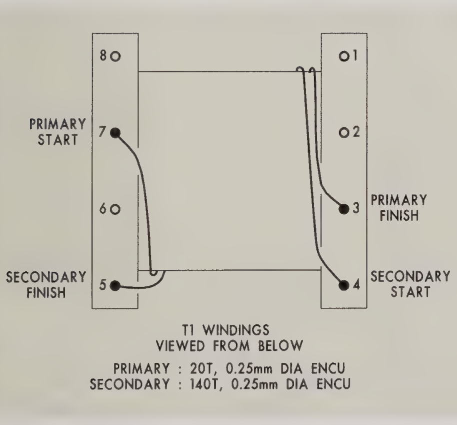

8
1
PRIMARY START
7
2
6
3
PRIMARY FINISH
SECONDARY FINISH
5
4
SECONDARY START
T1 WINDINGS VIEWED FROM BELOW
PRIMARY : 20T, 0.25mm DIA ENCU
SECONDARY : 140T, 0.25mm DIA ENCU

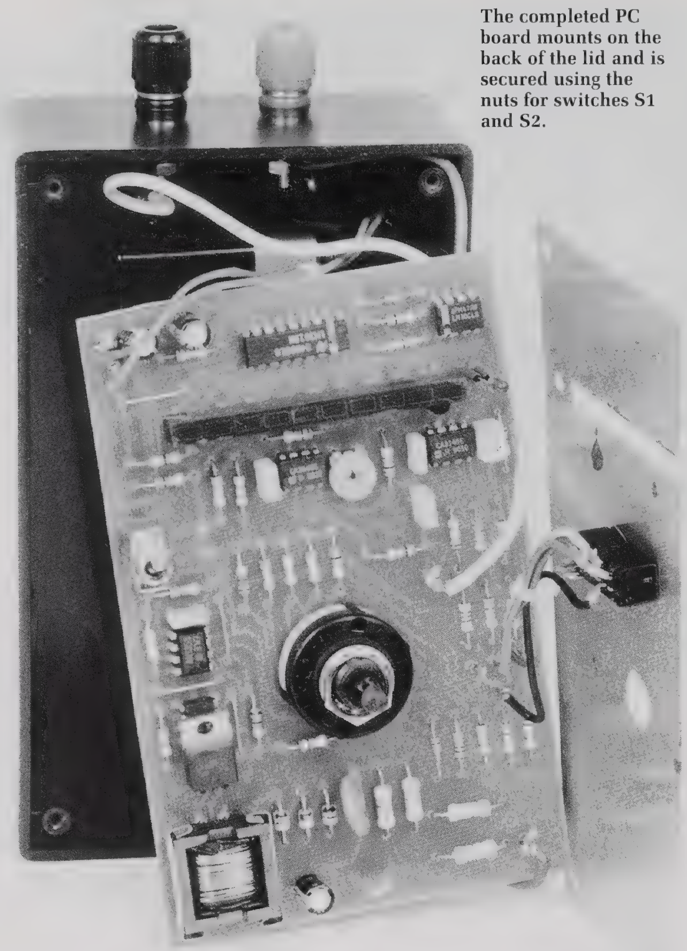
Fig.4: the primary of the transformer is wound first & covered with several layers of insulating tape before the secondary is installed.

Fig.3 shows the parts layout on the PC board. Begin the assembly by installing PC stakes at the external wiring points (11 in all). These are located at the (+) and (-) battery wiring points, the wiring points for S3 (1-4), the three wiring terminals for switch S1, and at the (+) and (-) terminal points.

Once the PC stakes are in, install the resistors, diodes and ICs. Don't just rely on the resistor colour codes – check each resistor using a digital multimeter, as some colours can be difficult to read. Take care to ensure that the semiconductors are correctly oriented.

The capacitors can go in next, followed by the transistors and the trimpot (VR1). Note that Q1 must be mounted at full lead length so that it can be bent horizontally over the adjacent .0039μF capacitor. This is necessary to allow clearance for the lid of the case, when it is later installed.

LEDs 1-10 (the bargraph) and LED11 can now be installed. Be sure to install the bargraph with its anode (A) adjacent to the 82Ω resistor. It should be mounted so that the top surface of the display is 19mm above the board,



The completed PC board mounts on the back of the lid and is secured using the nuts for switches S1 and S2.

so that it will later fit into a matching slot cut into the lid of the case. The top of LED11 should be 20mm above the board surface.

Switch S1 is soldered directly to its PC stakes but with its pins touching the top of the PC board. You may need to cut the PC stakes to length to do this. S2 is installed directly on the PC board after first cutting the shaft to a length suitable for the knob.

Transformer winding

Transformer T1 is wound with 0.25mm enamelled copper wire – see Fig.4. The primary is wound first, as follows: (1) remove the insulation from one end of the wire using a hot soldering iron and terminate this end on pin 7; (2) wind on 20 turns side-by-side in the direction shown and terminate the end on pin 3; (4) wrap a layer of insulating tape around this winding.

The secondary is wound on in similar fashion, starting at pin 4. Note that you will need to wind on the 140 turns in several layers. Use a layer of insulating tape between each layer and terminate the free end on pin 5.

The transformer is now assembled by sliding the cores into each side and then securing them with the clips. This done, insert the transformer into the PC board, making sure that it is oriented correctly, and solder the pins.

A standard plastic case measuring 158 x 95 x 52mm is used to house the assembled PC board. This is fitted with a self-adhesive front-panel label measuring 90 x 151mm.

Begin the final assembly by affixing the front panel label to the lid, then drill out and file the holes for the LED display, LED11, switches S1, S2 & S3, and the two terminals in the end of the case. Holes will also have to be drilled in the base of the case for the 9V battery holder.

This done, the front panel can be test fitted to the PC board. Check that everything lines up correctly and make any adjustments as necessary. You may need to adjust the height of the LED bargraph or LED11, for example. When everything is correct, set switch S2 fully anticlockwise and move its locking tab (found under the star washer) to position 5. This ensures that S2 functions as a 5-position switch only.

The external wiring can now be installed. Use light-duty hookup wire for the connections to S3 and the battery holder and mains-rated cable for the connections to the test terminals. Important: the leads to the test terminals must be kept well apart, as any leakage between them at the high test voltages used will affect readings.

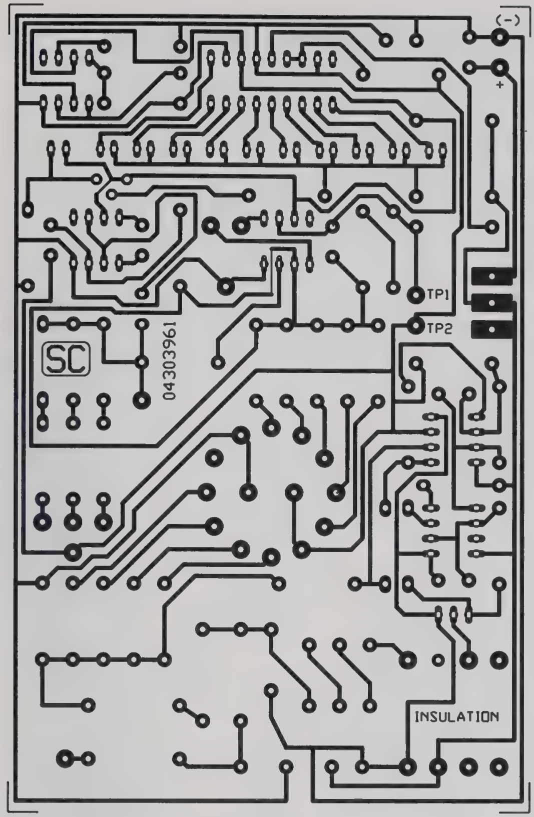
Testing

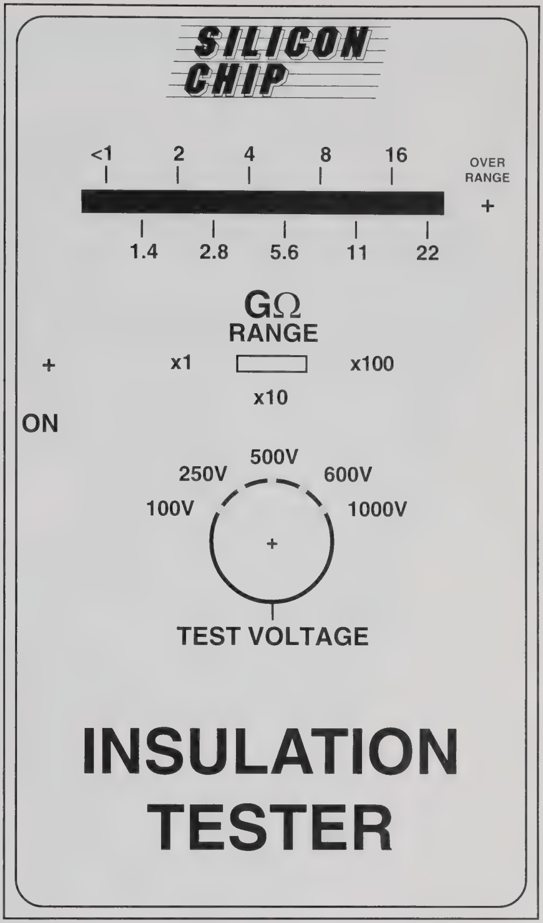
To test the unit, apply power and check that, initially, one of the LEDs in the bargraph display lights. Assuming that the test terminals are open circuit, the bargraph reading should then slowly increase until the overrange LED comes on. If this doesn't happen, check that the LEDs are oriented correctly.

Now check the circuit voltages with a multimeter. There should be about 9V between pins 4 & 8 of IC1; between pins 1 & 8 of IC2; between pins 7 & 4 of IC3, IC4 and IC5; and between pins 2 & 3 of IC6. There should also be a reading of 2V at TP2.

If everything checks out so far, select the 1000V (or higher) range on your multimeter and connect the positive meter lead to the cathode (striped end) of D3. Now check for the correct test voltages, as selected by S2. Note that if the output voltage is measured directly at the test terminals, the meter will show only about half the correct value because it loads the 9.4MΩ output impedance.

Next, set your multimeter to read DC mV and connect it between TP1 and TP2. This done, set the range switch to the x1 position and slowly





Figs.5 & 6: here are the full size artworks for the PC board and the front panel. Check your board carefully against the above pattern before mounting any of the parts, as any problems will be more difficult to locate later on.

adjust VR1 until you obtain a 0mV (or close to it as possible) reading. Note: nothing should be plugged into the test terminals during this procedure.

Once all the adjustments have been completed, fit the front panel to the board assembly and secure it by fitting the nuts to switches S1 and S2. The unit can then be installed in the case and the knob fitted to S2 to complete the assembly.

Test leads

It is important to note that maximum resistance readings cannot be obtained from this instrument if the test leads touch each other or are twisted together, or if a standard test lead set is used.

For measurements up to and beyond 220GΩ, we recommend high quality test leads such as those from the Fluke range. DSE Cat. Q1913 test leads (or an equivalent type) are also capable of meaningful results above 220GΩ, provided rubber gloves are worn and the leads are not touching a common surface.

Alternatively, you may be able to improve on a standard test lead set by insulating the probes with heatshrink tubing. In most cases the protective shroud on the test lead banana plugs will have to be cut away to allow them to be inserted into the banana sockets.

You can now check the unit by connecting the test leads across the terminals of an unwired switch. The leakage is then determined by first selecting the x1 range and then switching to the next range if necessary. If the display indicates 1GΩ on the x1 range, then the switch under test is either faulty or its contacts are closed.

Note that the unit will display a reading of 1GΩ even if the actual resistance is much lower than this.

Finally, when checking capacitors for leakage, be sure to select the correct test voltage. It is then necessary to wait until the capacitor fully charges before taking the reading. **SC**

WARNING!

Take care with fully charged capacitors since they can provide a nasty electric shock. Always discharge the capacitor after testing it by switching off the Insulation Tester with the probes connected. A 1μF capacitor will take about 10 seconds to discharge using this technique, while larger values will take proportionally longer.

A 10uH to 19.99mH Inductance Meter

2.53
μH
mH
SILICON CHIP
INDUCTANCE METER
0
1
2
3
4
5
6
7
8
9
10
SWITCH AND ADJUST FOR METER ZERO

This easy-to-build test instrument can measure inductances over the range from 10μH to 19.99mH with an accuracy of about 5%. It uses readily available parts and has a 4-digit LCD readout.

By RICK WALTERS

AN INDUCTANCE METER can be a handy test instrument in many situations. It can be used for servicing (eg, in TV sets), selecting coils for RF circuits, checking coils for switchmode power supplies and for measuring coils in many other applications.

The instrument to be described here measures from 10μH to 19.99mH over two ranges and has the twin virtues of being easy to build and easy to use. As shown in the photos, there are just three front panel controls: a range switch (μH or mH), a pushbutton switch and a potentiometer. An AC plugpack is used to supply power, so there is no on/off switch to worry about.

To make a measurement, you first connect the inductor to the test terminals and switch to the μH range. You then press the "Null" button and rotate the knob until the LCD panel meter reads zero, or as close to zero as you can get (ie, a null). This done, you release the button and read the inductance directly off the display.

If the meter over-ranges (ie, it only displays a 1 at the lefthand digit), you simply switch to the mH range before reading the inductance value from the meter. The value indicated on the scale by the potentiometer is the DC resistance of the inductor (although, in practice, this reading may not be all that accurate).

Block diagram

Fig.1 shows the block diagram of the Digital Inductance Meter. It uses a 3.2768MHz crystal oscillator (IC1a) to generate a precise clock frequency and this is divided by 20 and filtered by IC5 to give a 163.84kHz sinewave signal. In addition, the signal from the divide-by-20 stage is divided by 100 and filtered by IC6 to give a second frequency of 1638.4Hz.

Main Features

- Two ranges: 10-1999μH & 1-19.99mH
- Indicates inductor DC resistance
- Operates from a 9V AC plugpack supply
- Accuracy typically 5% from 10μH to 19.99mH

Range switch S2a selects between these two frequencies and feeds the selected signal to a nulling circuit. This circuit is used to null out the DC resistance of the inductor being measured. The output from the nulling circuit is then fed to positive and negative peak detectors and these in turn drive a digital panel meter (DPM).

Circuit details

Let's now take a look at the circuit diagram of the Inductance Meter – see Fig.2.

NAND gate IC1a and its associated components function as a square wave oscillator. It oscillates at a frequency of 3.2768MHz, as set by crystal X1. The 33pF, 270pF and 100pF capacitors provide the correct loading for the crystal and ensure that it starts reliably when power is applied.

Pushbutton switch S1 is used to disable the oscillator. Normally, the output of IC1a (pin 3) clocks the pin 15 (CA-bar) input of IC2b. However, when S1 is pressed, pin 1 is pulled low and IC1a's pin 3 output remains high. We'll explain why this is done later on.

IC2b, part of a 74HC390 dual 4-bit decade counter, divides the clock signal from IC1a by 10. The divided 327.68kHz output appears at pin 9 and in turn clocks pin 1 of IC3a.

IC3a is one half of a 74HC112 dual J-K flipflop. In operation, it toggles its Q and Q-bar outputs on each falling edge of the clock pulse and thus divides the frequency on its pin 1 input by 2. The resulting 163.84kHz square wave signal on the Q output (pin 5) is then applied to op amp IC5 which is configured as a Multiple Feedback Bandpass Filter (MFBF).

Because a square wave is made up of a fundamental sinewave frequency plus multiple harmonics, we can configure IC5 to recover virtually any harmonic. In this case, we are using IC5 to recover the 163.84kHz fundamental frequency, as determined by the three resistors and two capacitors between the output of IC3a and its inverting input.

The recovered 163.84kHz sinewave output appears on pin 6 of IC5 and due to the bandwidth limitations of the IC, it is a little "notchy". For this reason, it is further filtered using a 1.5kΩ resistor and a 470pF capacitor to remove these high frequency artefacts. This filter circuit also reduces the amplitude of the sinewave to around 5V peak-to-peak. The filtered sinewave is then fed to VR1 which is the calibration control for the μH (microhenry) range.

Similarly, for the mH range, IC3a's Q-bar output is fed to pin 4 of IC2a which in conjunction with IC1c and IC1d is wired as a divide-by-5 counter. Its output appears at pin 3 and clocks decade counter IC4. IC4 divides the frequency on its pin 15 input by 10 and in turn clocks JK flipflop IC3b which divides by two. The signal is then fed to MFBF filter stage IC6, in this case centred on 1638.4Hz.

The output from pin 6 of IC6 is a 1638.4Hz sinewave (also at 5V p-p) and this is fed to calibration control VR2. Range switch S2a selects between the two output frequencies and ap-

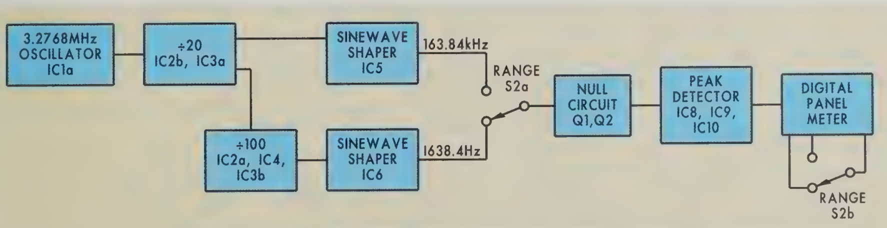


Fig.1: the block diagram for the Digital Inductance Meter. Two precise sinewave frequencies are derived and these are fed to a null circuit which contains the inductor under test. The following circuitry then measures the impedance of the inductor and displays its inductance in μH or mH.

Parts List

1 PC board, code 04107991, 124mm x 101mm
1 plastic case, Jaycar HB6094
1 front panel label
1 Digital Panel Meter, Jaycar QP5550 (or equivalent)
1 9V AC plugpack
1 chassis mount power socket, to suit plugpack
1 DPDT toggle switch (S1)
1 pushbutton switch, (PB1), Jaycar SP0710 (or equivalent)
1 speaker connector panel, Jaycar PT3000 (or equivalent)
1 knob to suit front panel
1 ferrite core set, Altronics L5300 (or equivalent)
1 bobbin, Altronics L5305 (or equivalent)
20m 0.25mm enamelled copper wire
2 5kΩ multi-turn trimpots (VR1-2)
1 10Ω wirewound potentiometer (VR3) (see text for alternative)
3 20kΩ vertical mounting trimpots (VR4-VR6)
1 3mm x 20mm bolt
1 3mm nut
1 3mm flat washer
1 3mm fibre washer
13 PC stakes

Semiconductors
1 74HC00 quad 2 input NAND gate (IC1)
1 74HC390 decade counter (IC2)
1 74HC112 dual JK flipflop (IC3)
1 4029 binary decade counter (IC4)
4 LM318 op amps (IC5, IC7-IC9)
1 TL071 op amp (IC6)
1 TL072 dual op amp (IC10)
1 7809 TO-220 9V regulator (REG1)
1 78L05 TO-92 5V regulator (REG2)
1 79L05 TO-92 -5V regulator (REG3)
2 BC559 PNP transistors (Q1,Q2)
4 1N914 silicon diodes (D1-D4)
2 1N4004 1A power diodes (D5,D6)
1 3.2768MHz crystal (X1), Jaycar RQ5271 (or equivalent)

Capacitors
4 470µF 16VW PC electrolytic
7 100µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
7 0.1µF monolithic ceramic
5 0.1µF MKT polyester
3 .01µF MKT polyester
1 .0047µF MKT polyester
1 470pF ceramic or MKT polyester
2 270pF NPO 5% ceramic
1 220pF NPO 5% ceramic
3 100pF NPO 5% ceramic
1 33pF NPO 5% ceramic
2 22pF NPO 5% ceramic

Resistors (0.25W, 1%)
1 8.2MΩ (select on test)
1 1MΩ
2 820kΩ
2 200kΩ
5 100kΩ
1 68kΩ
1 47kΩ
1 33kΩ
2 20kΩ
14 10kΩ
1 7.5kΩ
2 5.6kΩ
3 4.7kΩ
1 1.5kΩ
2 1kΩ
2 470Ω
2 270Ω
1 180Ω (calibration)
4 100Ω
1 3.3Ω (calibration)

plies the selected signal to the bases of transistors Q1 and Q2 via a 10µF capacitor.

Nulling circuit

OK, we now have two precise frequencies, either of which can be selected and fed to the bases of PNP transistors Q1 and Q2. These are wired in a nulling circuit. Let's take a closer look at their operation.

The thing to remember here is that the emitter of a PNP transistor is always 0.6V more positive than its base (0.6V more negative for an NPN transistor). Thus, if the base of Q1 is at 5.7V, its emitter sits at 6.3V. Because the supply voltage is 9V, this means that 2.7V must appear across the associated 270Ω emitter resistor and this translates into a current of 10mA through the resistor.

This (constant) current will also flow in the collector circuit of Q1, regardless of the load resistance (provided this resistance is not too large). If the base of Q1 is now modulated by a sinewave, its collector current will vary sinusoidally, the average still being 10mA.

Q2 has the same value of emitter resistor as Q1 so its collector current will be the same as Q1's; ie, 10mA. This collector current flows through potentiometer VR3 to ground.

Note that high beta (gain) transistors are used for Q1 and Q2 to reduce the base current, which is a small fraction of the emitter current.

Because the current through Q2 is 10mA, VR3 (10Ω) will have the same voltage across it as an inductor with a 10Ω resistance connected between Q1's collector and ground. This position is labelled on the circuit as "DUT", which means "Device Under Test". The scale for VR3, on the front panel, is calibrated from 0-10. We will come back to it shortly.

Q1's collector is connected to the positive (red) input terminal of the inductance meter, while the other input terminal is connected to ground. When an inductor is connected across these terminals, a voltage appears across it. This voltage consists of two components: (1) a voltage due to the DC resistance of the inductor (as just described); and (2) a voltage due to the inductive reactance.

In operation, Q1 drives pin 3 of differential amplifier stage IC7 via a resistive divider (10kΩ & 20kΩ), while Q2 drives the pin 2 input via VR3. IC7 and the following parts, including the LCD readout, function as a digital voltmeter.

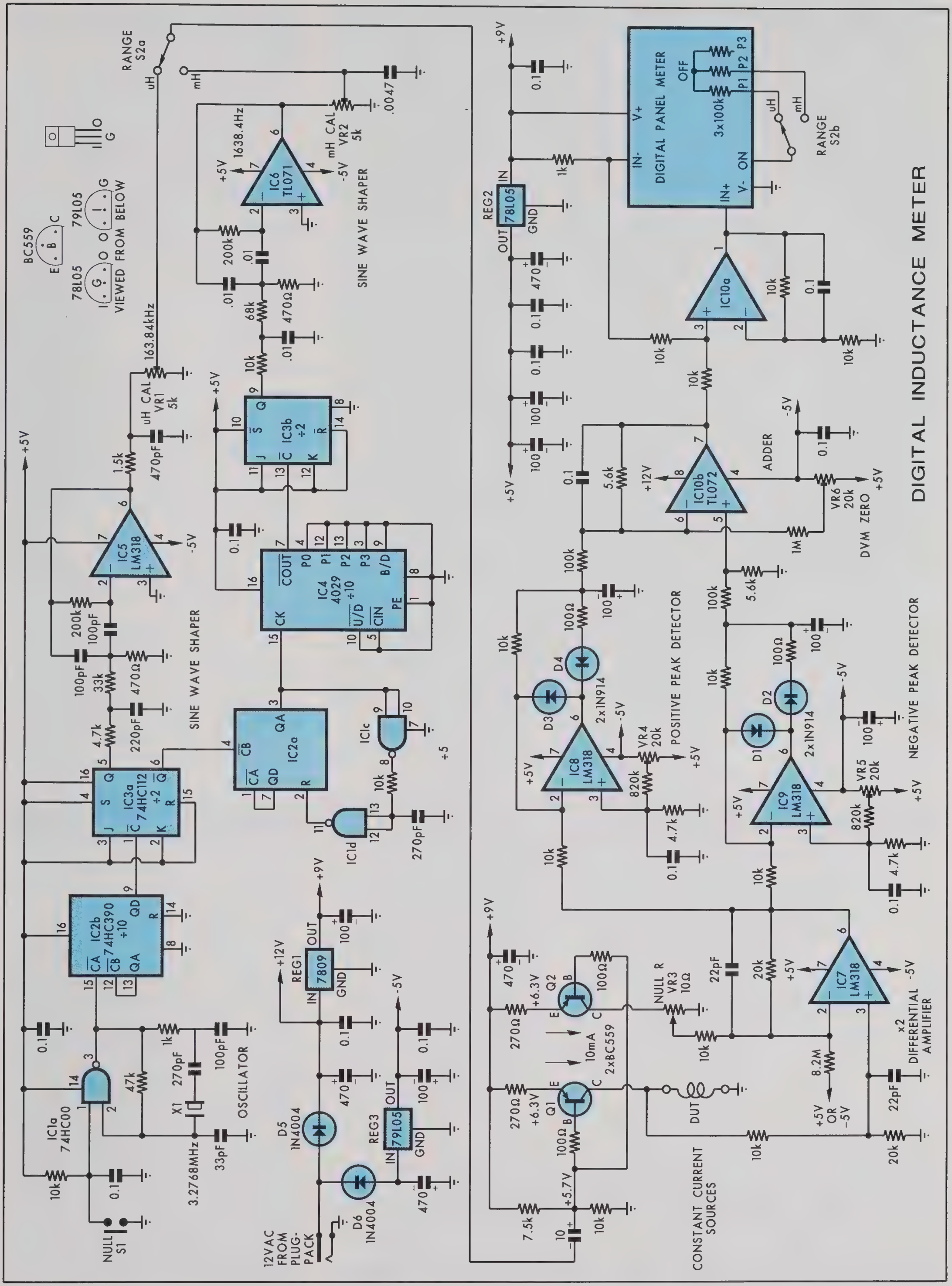
Before taking a measurement, the resistive voltage component must be cancelled out. This is done by pressing switch S1 which shuts down oscillator stage IC1a and effectively "kills" the sinewave signals selected by S2a. Potentiometer VR3 is then adjusted so that the signal on pin 2 of differential amplifier stage IC7 is the same as the signal on pin 3, as indicated by a 0.00 reading on the LCD readout.

Note that when the meter reads zero, the control knob on VR3 indicates the inductor's DC resistance on the calibrated scale.

Making the measurement

If S1 is now released, the selected sinewave modulates the 10mA collector current of Q1. This in turn generates a sinusoidal voltage across the inductor (DUT), the amplitude of which is proportional to the inductance. The resulting sinewave signal from IC7 is subsequently rectified by

Fig.2: the complete circuit diagram of the Digital Inductance Meter. IC1 is the oscillator, while ICs2-5 divide the oscillator signal to produce the two precise sinewave frequencies. Constant current sources Q1 & Q2 form the null circuit.



DIGITAL INDUCTANCE METER

RANGE S2a
uH
mH
.0047
mH CAL VR2 5k
1638.4Hz
IC6 TL071
+5V
-5V
200k
.01
470Ω
68k
10k
SINE WAVE SHAPER
BC559
E B C
78L05
79L05
I G O
O I G
VIEWED FROM BELOW
163.84kHz
uH CAL VR1 5k
470pF
1.5k
+5V
IC5 LM318
100pF
33k
220pF
4.7k
IC3b ÷2
IC4 4029 ÷10
COUT P0 P1 P2 P3 B/D CK U/D CIN PE
0.1
IC3a 74HC112 ÷2
IC2a
IC2b 74HC390 ÷10
CA CB QA QD R
IC1c
IC1d
÷5
270pF
IC1a 74HC00
47k
1k
X1 3.2768MHz
33pF
OSCILLATOR
NULL S1
12VAC FROM PLUG-PACK
D5 1N4004
D6 1N4004
REG1 7809
REG3 79L05
IN OUT GND
+12V
+9V
-5V
470
100
+9V
REG2 78L05
DIGITAL PANEL METER
V+ IN- IN+ V- OFF ON
3x100k
P1 P2 P3
RANGE S2b
IC10a
IC10b TL072
ADDER
5.6k
100k
VR6 20k DVM ZERO
1M
POSITIVE PEAK DETECTOR
NEGATIVE PEAK DETECTOR
D1 D2 D3 D4
2x1N914
IC8 LM318
IC9 LM318
VR4 20k
VR5 20k
820k
100Ω
IC7 LM318
x2 DIFFERENTIAL AMPLIFIER
22pF
20k
8.2M
+5V OR -5V
NULL R VR3 10Ω
Q1 Q2
2xBC559
10mA
+6.3V
+5.7V
270Ω
7.5k
DUT
CONSTANT CURRENT SOURCES

peak detectors IC8 & IC9, summed in IC10b and applied to the digital panel meter.

IC8 is used to detect and rectify the positive sinewave peaks. It works like this: when the output of IC7 swings positive, pin 6 of IC8 swings negative and charges a 100μF capacitor via D4 and a series 100Ω resistor to the peak level of the waveform. As a result, the voltage across the 100μF capacitor is equal to but opposite in polarity to the peak positive input voltage.

D4 prevents the 100μF capacitor from discharging as the input level falls and the voltage on pin 6 starts to rise. In addition, D3 is reverse biased during this time and so has no effect.

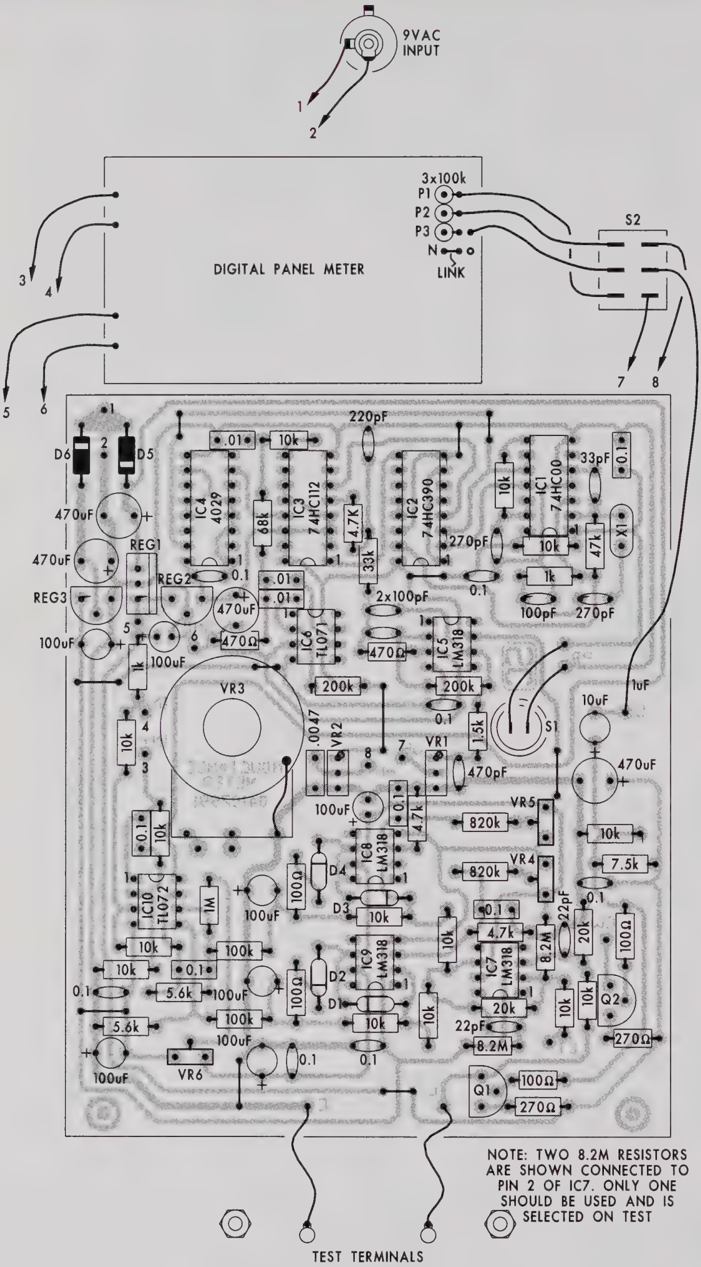
Conversely, when IC7's output swings negative, IC8's output swings positive and is clamped by D3 so that it is 0.6V above the virtual earth input at pin 2. As a result, the voltage across the 100μF capacitor is "topped up" only during positive signal excursions at the output of IC7.

IC9, the negative peak detector, works in exactly the same way but with opposite polarity. It charges its 100μF capacitor to the positive peak of the applied waveform. Thus, the positive peak voltage is represented by a negative DC voltage, while the negative peak voltage is represented by a positive DC voltage across the lower 100μF capacitor.

Due to the bandwidth limitations of the ICs, this rectification is not perfect at the higher frequency. This limits the accuracy below 10μH and readings below this value should only be used for comparison measurements.

The output signals from the positive and negative peak detectors are summed in amplifier stage IC10b. This stage operates with a gain of .056, as set by the 5.6kΩ and 100kΩ feedback resistors, to match the signal to the sensitivity of the DPM (200mV FSD). IC10b drives op amp IC10a which operates with a gain of two and this then drives the IN+ input of the panel meter.

Note that the IN- input of the panel meter takes its reference from the 9V supply rail and normally sits at about 6.3V. As a result, IC10a must also operate as a level shifter. This is achieved by biasing pin 3 of IC10 to half the IN- reference voltage (using two 10kΩ resistors). Thus, under no signal conditions, pin 1 also sits at 6.3V and the meter reading is zero.


9VAC
INPUT
1
2
3x100k
P1
P2
P3
N
LINK
DIGITAL PANEL METER
S2
3
4
5
6
7
8
D6
D5
470uF
470uF
REG1
REG2
REG3
100uF
.01
10k
220pF
IC4
4029
68k
IC3
74HC112
4.7K
33k
IC2
74HC390
270pF
10k
IC1
74HC00
33pF
0.1
X1
47k
10k
1k
100pF
270pF
0.1
.01
.01
470uF
470Ω
IC6
TL071
2x100pF
470Ω
IC5
LM318
1k
100uF
VR3
200k
200k
0.1
1.5k
S1
10uF
1uF
470uF
10k
.0047
VR2
VR1
470pF
100uF
0.1
4.7k
820k
VR5
10k
7.5k
0.1
10k
IC8
LM318
D4
820k
VR4
0.1
IC10
TL072
1M
100uF
100Ω
D3
10k
0.1
22pF
10k
4.7k
8.2M
20k
100Ω
10k
100k
10k
0.1
IC9
LM318
D2
IC7
LM318
10k
10k
Q2
0.1
5.6k
100uF
100Ω
D1
10k
20k
5.6k
100k
22pF
270Ω
100uF
10k
8.2M
100uF
VR6
0.1
0.1
Q1
100Ω
270Ω
TEST TERMINALS

NOTE: TWO 8.2M RESISTORS ARE SHOWN CONNECTED TO PIN 2 OF IC7. ONLY ONE SHOULD BE USED AND IS SELECTED ON TEST

Fig.3: install the parts on the PC board as shown here, taking care to ensure that all polarised parts are correctly oriented. Note that two 8.2MΩ resistors are shown connected to pin 2 of IC7 but only one is used in practice and is selected on test (see text). Note also that the metal case of the pot is connected to earth via one of its terminals.

Table 1: Capacitor Codes

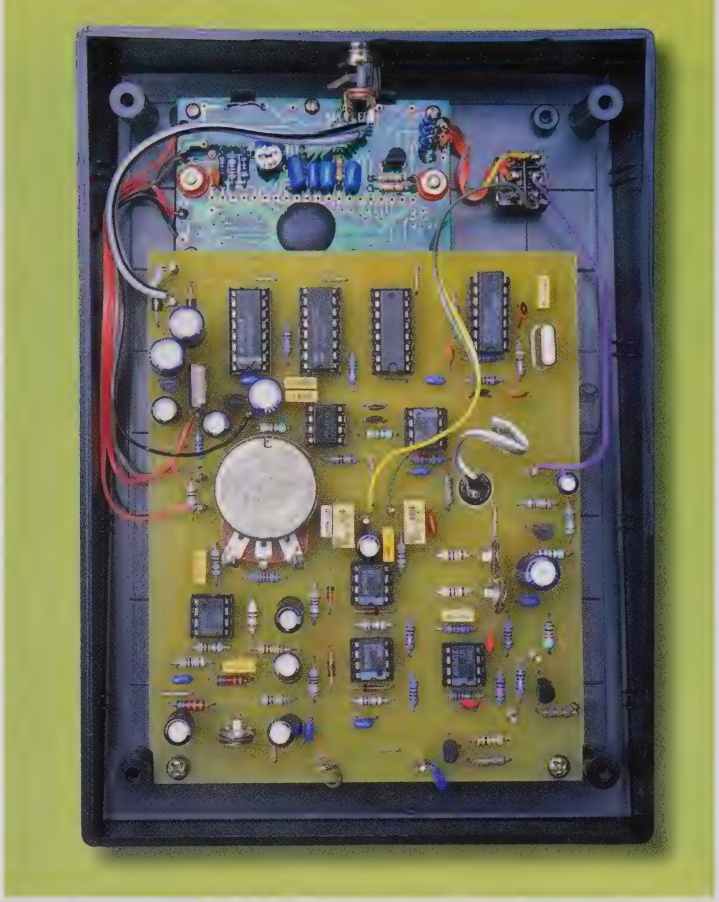
☐	Value	IEC Code	EIA Code
☐	0.1µF	100n	104
☐	.01µF	10n	103
☐	.0047µF	4n7	472
☐	470pF	470p	471
☐	270pF	270p	271
☐	220pF	220p	221
☐	100pF	100p	101
☐	33pF	33p	33
☐	22pF	22p	22

Trimpot VR6 is used to compensate for any offset voltage at the output of IC10a and allows us to set a zero reading on the DPM when the output of IC7 is at ground. Similarly, VR4 and VR5 compensate for any offset voltages at the outputs of the peak detectors.

Range switch S2b switches the decimal point on the panel meter, so that it displays the correct value when we switch from µH to mH. In effect, this switch divides by 10 while S2a divides by 100, so that we get an overall range division of 1000 when switching from the µH to the mH range.

Power supply

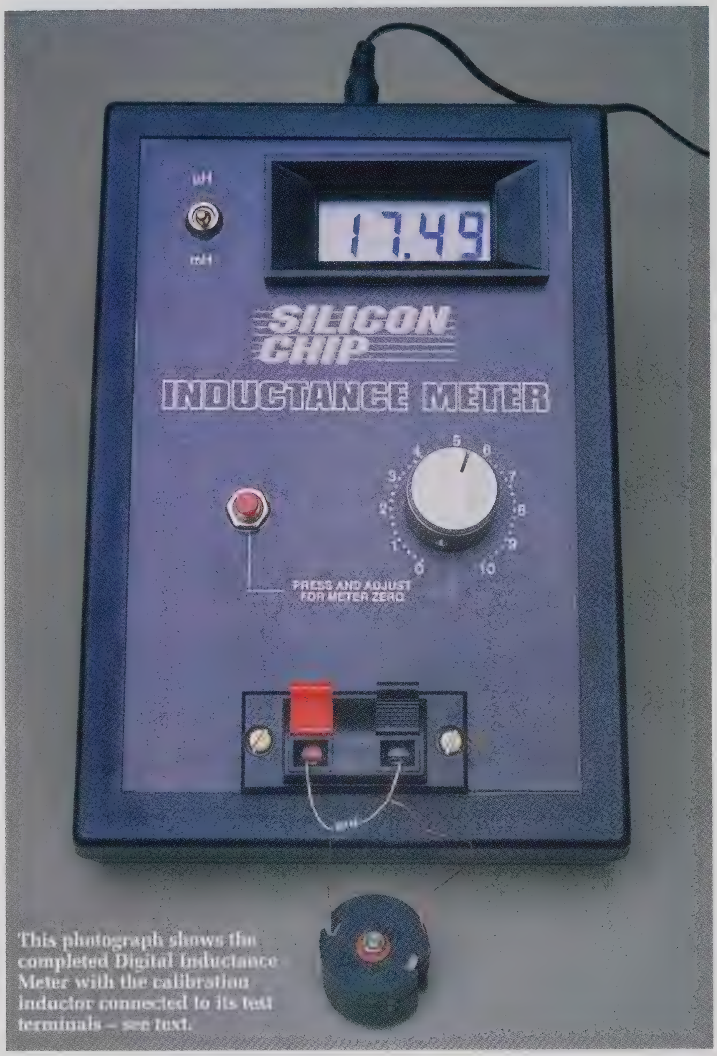
Power for the Digital Inductance Meter is derived from a 12VAC AC plugpack supply. Its output is half-wave rectified by diodes D5 and D6 to derive +12V and -12V rails and these are filtered and fed to 3-terminal regu-



Quite a few changes were made to the PC board of the Digital Inductance Meter after this photograph was taken.

Table 2: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	8.2MΩ	grey red green brown	grey red black yellow brown
☐	1	1MΩ	brown black green brown	brown black black yellow brown
☐	2	820kΩ	grey red yellow brown	grey red black orange brown
☐	2	200kΩ	red black yellow brown	red black black orange brown
☐	5	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	68kΩ	blue grey orange brown	blue grey black red brown
☐	1	47kΩ	yellow violet orange brown	yellow violet black red brown
☐	1	33kΩ	orange orange orange brown	orange orange black red brown
☐	2	20kΩ	red black orange brown	red black black red brown
☐	14	10kΩ	brown black orange brown	brown black black red brown
☐	1	7.5kΩ	violet green red brown	violet green black brown brown
☐	2	5.6kΩ	green blue red brown	green blue black brown brown
☐	3	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	1	1.5kΩ	brown green red brown	brown green black brown brown
☐	2	1kΩ	brown black red brown	brown black black brown brown
☐	2	470Ω	yellow violet brown brown	yellow violet black black brown
☐	2	270Ω	red violet brown brown	red violet black black brown
☐	1	180Ω	brown grey brown brown	brown grey black black brown
☐	4	100Ω	brown black brown brown	brown black black black brown
☐	1	3.3Ω	orange orange gold brown	orange orange black silver brown



This photograph shows the completed Digital Inductance Meter with the calibration inductor connected to its test terminals – see text.

lators REG1 & REG3 respectively. REG1 provides a +9V rail, while REG3 provides a -5V rail. In addition, REG1 feeds REG2 which provides a regulated +5V rail.

The ±5V rails supply most of the op amp stages, while the +9V rail supplies the digital panel meter and the constant current sources in the null circuit. The +12V rail is used for the positive supply to IC10, as its output needs to swing up to near the 9V supply of the DPM.

Putting it together

Building the circuit is a lot easier than understanding how it works. Most of the parts are mounted on a single PC board and this is coded 04107991. This, together with the digital panel meter, fits inside a standard plastic case with a sloping front panel.

As usual, check the PC board for etching defects by comparing it with the published pattern (Fig.4). Any defects should be repaired before proceeding. In addition, part of the PC board will have to be filed away along the bottom lefthand and bottom righthand edges, so that the board will fit between the mounting pillars of the case.

Check also that the body of switch S1 fits through its matching clearance hole in the board. Enlarge this hole with a tapered reamer if necessary, so that it clears the switch. The same goes for the threaded bush of pot VR3.

Fig.3 shows the assembly details. Begin by fitting 13 PC stakes for the external wiring points, then fit the 11 wire links on the top of the board (including the one under VR3). This done, fit the resistors, diodes and transistors. Table 2 shows the resistor colour codes but check them with a DMM as well, just to make sure.

Take care to ensure that all the transistors and diodes are installed the correct way around and make sure the correct part is used at each location.

Once these parts are in, install the capacitors (watch the polarity of the electros), the regulators and the ICs. We used IC sockets in the prototype but suggest that you solder your ICs directly to the PC board. Again, be sure to use the correct device in each location and note that the ICs don't all face in the same direction.

The trimpots can now all be installed, followed by potentiometer (VR3). As shown in the photo, VR3 is installed from the component side of the PC board and is secured using a nut on the copper side. Its terminals are connected to their pads on the PC board using short lengths of tinned copper wire.

Once the pot is in, you have to run two insulated wire links between its terminals and points CT & CW on the PC board – see Fig.4. These points are located near Q2, towards the bottom righthand corner. Note also that the metal case of the pot is connected to earth via one of its terminals.

That completes the board assembly. Before placing it to one side though, go over your work carefully and check for errors. In particular, check for missed solder joints and incorrectly placed parts.

Final assembly

Next, attach the artwork to the front panel and use it as a drilling template for the switches, the potentiometer, the test terminals and the panel meter. The square cutout for the meter is made by first drilling a series of small holes around the inside of the marked area, then knocking out the centre piece and filing the edges to shape.

This done, use a sharp chisel to

remove the short mounting pillar inside the case, to prevent it from fouling the panel meter. You will also have to drill a hole in the top rear panel for the 3.5mm power socket – see photo. Be sure to position this hole so that the socket clears the panel meter when it is mounted.

The various components can now all be installed in the case, starting with the switches and the input connector block which carries the test terminals. Bend the lugs on the input connector block so that they are parallel to the front panel, to prevent them shorting to the PC board. The board can then be fitted inside the case and secured using two self-tapping screws into the short mounting pillars.

Before fitting the digital panel meter, it should have a link fitted from N to OFF (to disable the polarity indication). In addition, you have to fit three 100kΩ resistors from P1, P2 and P3 to OFF. These modifications are all shown on Fig.3 (do not forget the link).

The panel meter we used has an external dress bezel with two captive mounting screws. This bezel is mounted from the front and the panel meter then fitted over the screws and secured using nuts and fibre washers.

The assembly can now be completed by running the point-to-point wiring. Note the connections between S2 and the panel meter. **In particular, the middle lefthand terminal of S2 goes to the ON pad on the meter board (not to resistor P3). By contrast, the top and bottom lefthand terminals are connected to the resistors on P2 and P1 respectively.**

Test & calibration

Before you begin testing, you need to wind an inductor which is used later during the calibration procedure. To do this, wind around 300 turns of 30 B&S wire on the L5305 bobbin, then fit the cores and clamp them together using a 20mm bolt, flat washer, fibre washer and nut.

Once the coil has been wound, clean and tin the ends, then connect a 180Ω 1% resistor in parallel with it. Now put the coil to one side – you'll need it shortly, for Step 7 of the following procedure.

To test the unit, apply power and check that D5's cathode is at about 12V. This voltage will depend on the particular plugpack you use and is not too critical. Next check the +9V,

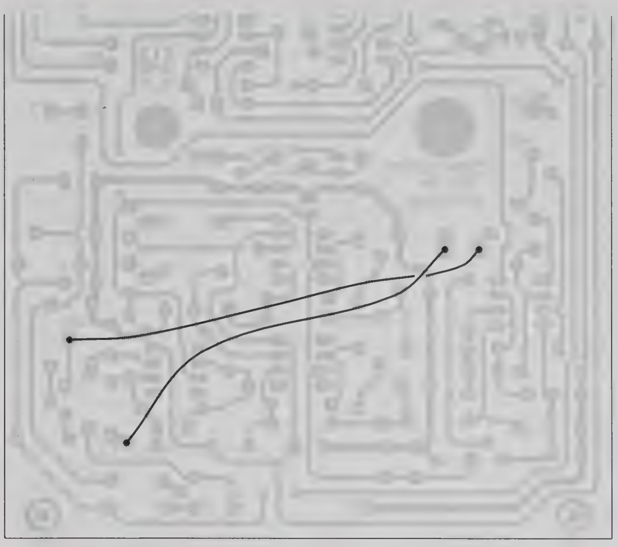


Fig.4: two insulated flying leads must be run on the copper side of the PC board, between the pot terminals and points CT & CW, as shown in this diagram.

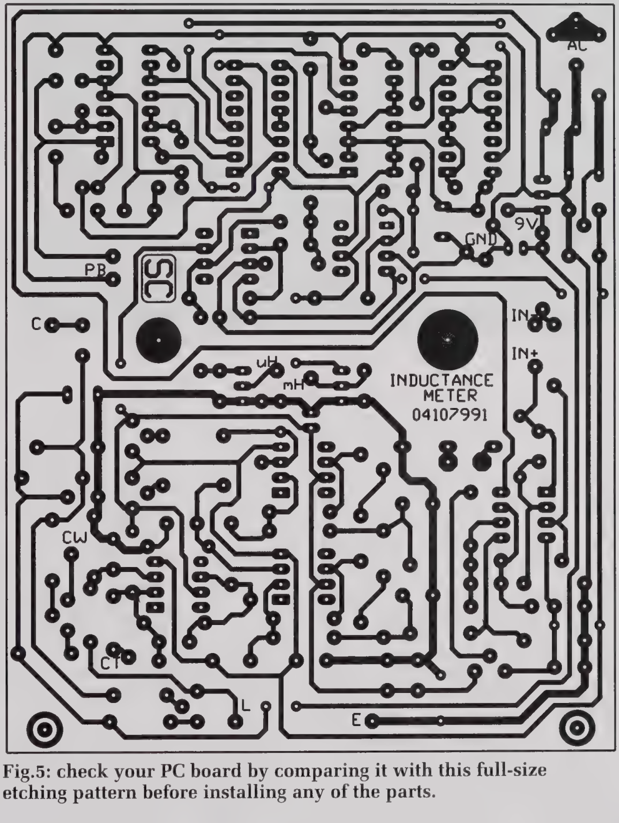


Fig.5: check your PC board by comparing it with this full-size etching pattern before installing any of the parts.

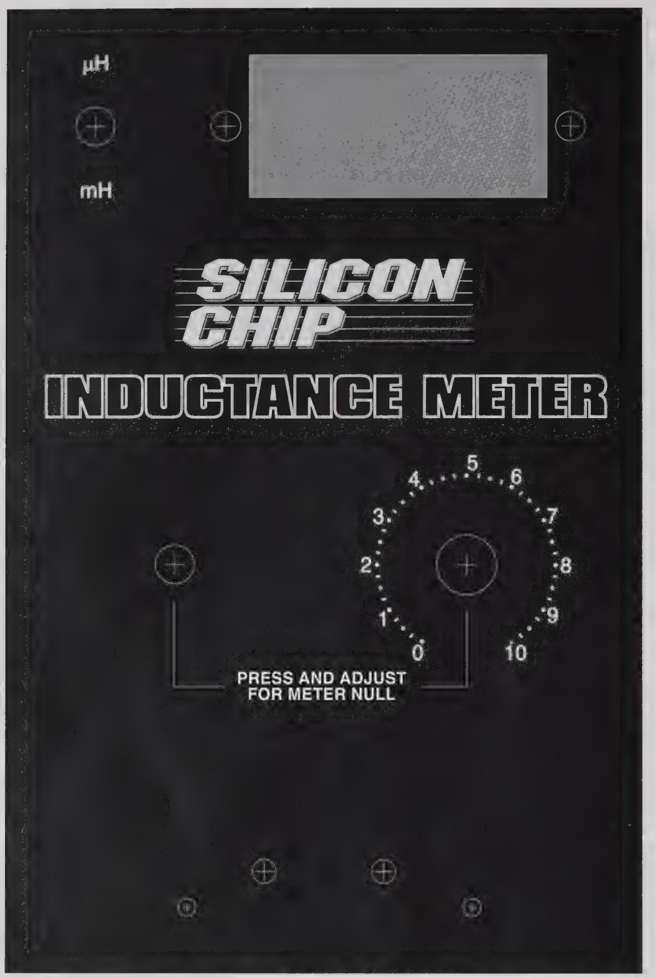


Fig.6: this full-size artwork can be used as a drilling template for the front panel.

+5V and -5V rails – these should all be within 5%. The panel meter should show a reading of around 16.00 or 160.0, depending on the range.

Now check the supply rails at the IC pins. If these are OK, you are ready to calibrate the instrument using the following step-by-step procedure:

Step1: connect a multimeter across the test terminals and set it to a range suitable for measuring 10mA DC.

Step 2: press S1 and check the current on the multimeter. It should be close to 10mA.

Step 3: release S1, rotate VR3 fully anticlockwise (0Ω), remove the multimeter and connect a 3.3Ω resistor across the test terminals.

Step 4: switch your multimeter to a low voltage range and connect it between pin 6 of IC7 and ground. Short switch S1's terminals using an alligator clip, then adjust VR3 (on the front panel) for a 0V (or as close as you can get) reading on the multimeter.

Step 5: connect the multimeter across the 100µF capacitor at the output of IC8 and (with S1 still shorted) adjust VR4 for a reading of 0V. Now adjust VR5 for 0V across the 100µF capacitor at the output of IC9.

Step 6: adjust VR6 for a zero reading on the panel meter and remove the shorting clip from S1.

Step 7: remove the 3.3Ω resistor from the test terminals and fit the inductor that you wound earlier (with its parallel 180Ω 1% resistor).

Step 8: rotate VR3 to the zero ohms position and measure the voltage on pin 6 of IC7. It must be adjusted to zero by fitting a resistor between pin 2 and either the +5V or -5V rail. Two sets of pads have been placed on the PC board for the resistor, from pin 2 to each supply. Our unit needed an 8.2MΩ resistor to the negative rail.

Step 9: set S2 to µH and adjust VR1 until the panel meter reads 174.9.

Step 10: switch to the mH range and adjust VR2 for a reading of 17.49.

That completes the calibration procedure. You can now close the case and begin using your new inductance meter.

By the way, if you find that you cannot zero (or null) the panel meter when measuring an inductor, even with VR3 rotated fully clockwise, it means that the resistance of the inductor is greater than 10Ω. Despite this, the inductance reading displayed when S1 is released should be close to the correct value.

What if it won't work?

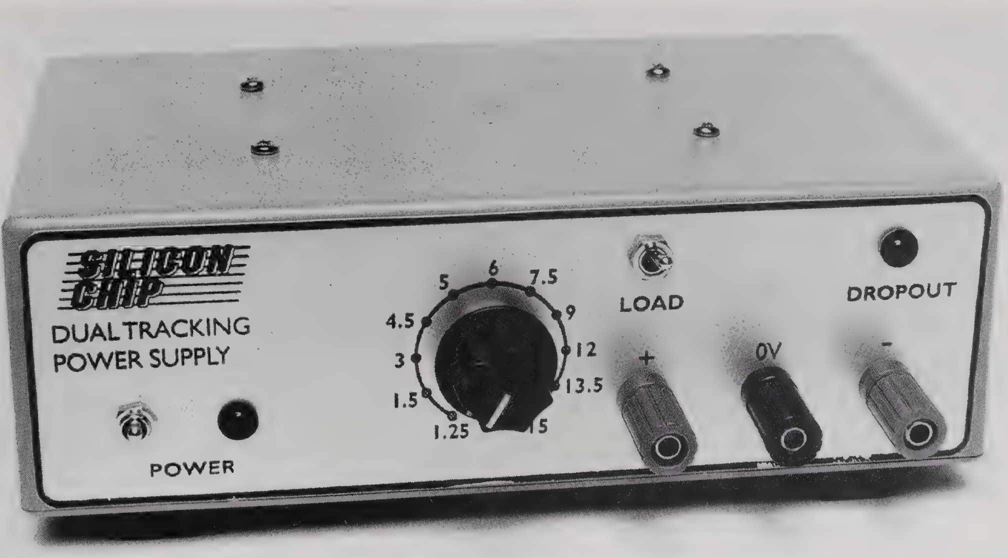
If you have problems, the first step is to check your soldering. In particular, look for missed solder joints and shorts between adjacent tracks and IC pins.

A few voltage checks can also help pinpoint problems. First, check for + 2.5V on pins 5, 6 and 9 of IC3. Pin 6 of IC5 and pin 6 of IC6 should be around 0V DC and 4-5V AC. Most meters will give quite a low reading on the AC output of IC5. As long as you get an indication, the signal is probably OK. The bases of Q1 and Q2 should be at 5.7V and their emitters at 6.3V. The collector of Q2 should read 100mV.

Note that when the unit is working properly and there is no inductor across the terminals, the meter will read around 16.00 or 160.0, depending on the range. This is due to the positive peak detector swinging to full output and is normal.

Variations

VR3 can be changed if you wish to measure inductors with DC resistances greater than 10Ω. For example, a 25Ω pot will allow inductors with resistances up to 25Ω to be measured. Naturally you will have to recalibrate the potentiometer scale or you can simply multiply the front panel reading by 2.5. **SC**



Beginner's Variable Dual-Rail Power Supply

If you're just beginning in electronics, then you'll probably baulk at building a mains-operated power supply. This project uses a plugpack which means that you can make your own variable dual-rail power supply without worrying about mains wiring.

When it comes to experimenting in electronics, power supplies are a bit of a "chicken and egg" situation. To experiment with circuits, you need a power supply but unless you have the necessary knowledge already, building a mains-powered supply is beyond most beginners.

The alternative is to run all of your circuits from batteries or buy a ready-made supply. Either option is expensive. So in the interests of making it easier to start experimenting, we've come up with this dual-rail power supply which runs from a 16V AC plugpack. It's capable of providing output voltages ranging from ±1.25V DC to ±15V DC at currents up to 500mA (see Fig.1).

The beauty of this design is that it doesn't require any external mains wiring! All the mains wiring is contained inside the plugpack, leaving you with just the low-voltage AC output which connects straight into the project.

In order to keep costs down, the output voltage is varied in 11 switched steps. This eliminates the need for an output voltage meter since the precise value can be directly read off the switch position. The 11 switched voltage ranges are: 1.25V, 1.5V, 3V, 4.5V, 5V, 6V, 7.5V, 9V, 12V, 13.5V & 15V. Both supply rails are protected against short circuits and voltages generated by external loads, while a LED indicator lights if the supply stops regulating.

Another worthwhile feature is the provision of a "load" switch. This allows the power to the load to be switched on and off while keeping the supply switched on.

The output current capabilities of the supply are relatively modest but should be more than adequate for most projects. Fig.1 plots the maximum current that can be delivered at various output voltages. As can be seen, the supply is capable of delivering 250mA or more for voltages from 1.5V up to about 14V, with a maximum of 500mA at 7.5V. Note that these figures assume a 16VAC 1A plugpack supply.

By now, some readers will be ask-

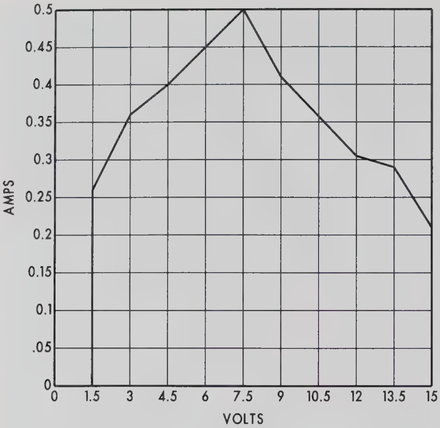


Fig.1: this graph plots the maximum output current from the supply for voltage settings between 1.5V & 15V (16VAC 1A plugpack). The supply is capable of delivering 250mA or more over most of the range.

ing “what is a dual-rail power supply?” It’s quite straightforward really – a dual-rail power supply has both positive and negative output voltage rails, as well as the ground (or zero volt) rail. Most projects and circuits you build will only require the positive output and the ground rail. This is basically the same as if you connected a battery of the same voltage to the circuit you’re building.

However, you’ll also come up against circuits which use operational amplifiers (op amps) and these require both positive and negative supply rails. That’s where the dual-rail power supply comes in. It can power op amp circuits with ease and so is just that much more versatile than a standard single rail supply.

An important feature of this design is that the negative supply rail automatically tracks the positive supply rail. This means that the two rails always have the same absolute value. Thus, if you set the positive output to +12V, the negative rail will be at -12V.

And here we should clear up a common misconception regarding dual rail supplies. Despite what many people think, it’s quite possible to use the positive and negative rails to obtain a much higher output voltage than is possible by simply connecting between one of these rails and the 0V rail.

For example, if you want a 30V single-rail supply, simply set the supply to give ±15V and connect the circuit across these outputs. Another way of looking at this is simply to consider that there is 30V between the two outputs. So a dual-rail ±1.25-15V variable power supply can also function as a 2.5-30V single rail supply.

Parts List

1 plastic case, 198 x 113 x 62mm
1 PC board, code 04110941, 102 x 57mm
1 front panel label
1 red 4mm binding post
1 black 4mm binding post
1 blue 4mm binding post
1 SPDT toggle switch (S1)
1 DPDT toggle switch (S2)
1 12-position 1-pole rotary switch (S3)
1 knob to suit S3
2 LED bezels
1 16VAC 1A plugpack
1 3.5mm power socket
2 mini U heatsinks
4 rubber feet

Semiconductors
1 LM358 dual op amp (IC1)
1 LM317 3-terminal regulator (REG1)
1 LM337 3-terminal regulator (REG2)
6 1N4004 diodes (D1-D6)
6 1N914 diodes (D7-D12)
2 15V 1W zener diodes (ZD1,ZD2)
2 5mm red LEDs (LED1,LED2)

Capacitors
2 470µF 25VW electrolytics
2 100µF 25VW electrolytics
4 1µF 63VW electrolytics
1 0.1µF 63VW MKT polyester

Resistors (0.25W, 1%)
1 4.7MΩ
2 47kΩ
1 22kΩ
2 3.3kΩ
1 2.7kΩ
3 1kΩ
1 680Ω
1 560Ω
1 470Ω
2 330Ω
1 270Ω
1 220Ω
1 180Ω
2 150Ω
2 120Ω
1 56Ω
1 27Ω

Miscellaneous
Machine screws & nuts, washers, hook-up wire.

How it works

The circuit for the Beginner’s Dual Rail Power Supply uses only standard components which you can find in any virtually electronics store. If you’ve got a parts bin handy, you’ll probably have a few parts that are suitable already.

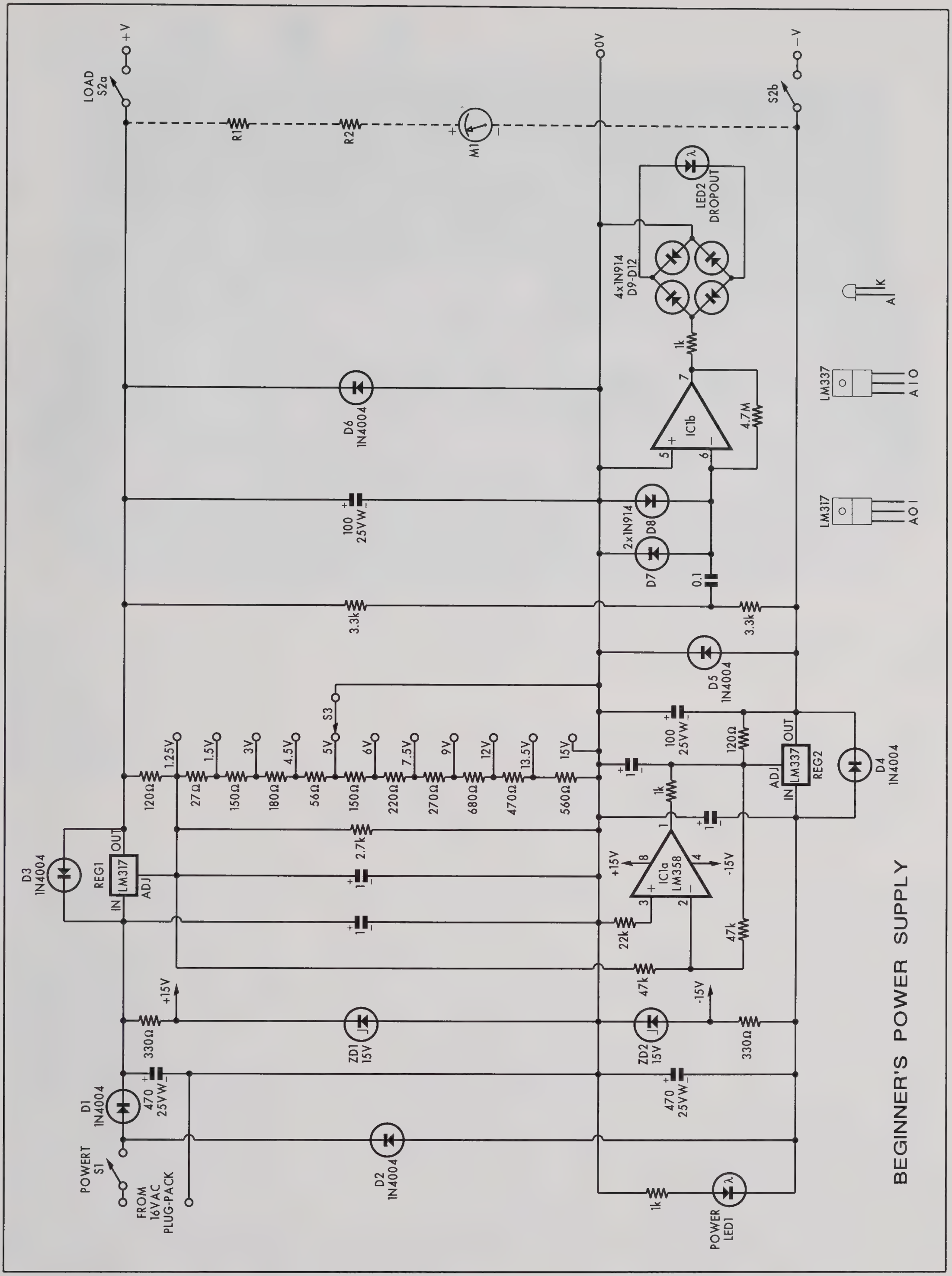
Let’s take a look at the circuit – see Fig.2. The plug pack takes care of all of the mains wiring and steps the 240VAC mains voltage down to a suitable 16VAC for our circuit. This is fed via power switch S1 to rectifier diodes D1 & D2 to produce unregulated plus and minus DC rails of about 20V.

These DC rails are filtered by two 470µF electrolytic capacitors and fed to LM317 and LM337 3-terminal regulators. These provide the adjustable plus and minus supply outputs respectively.

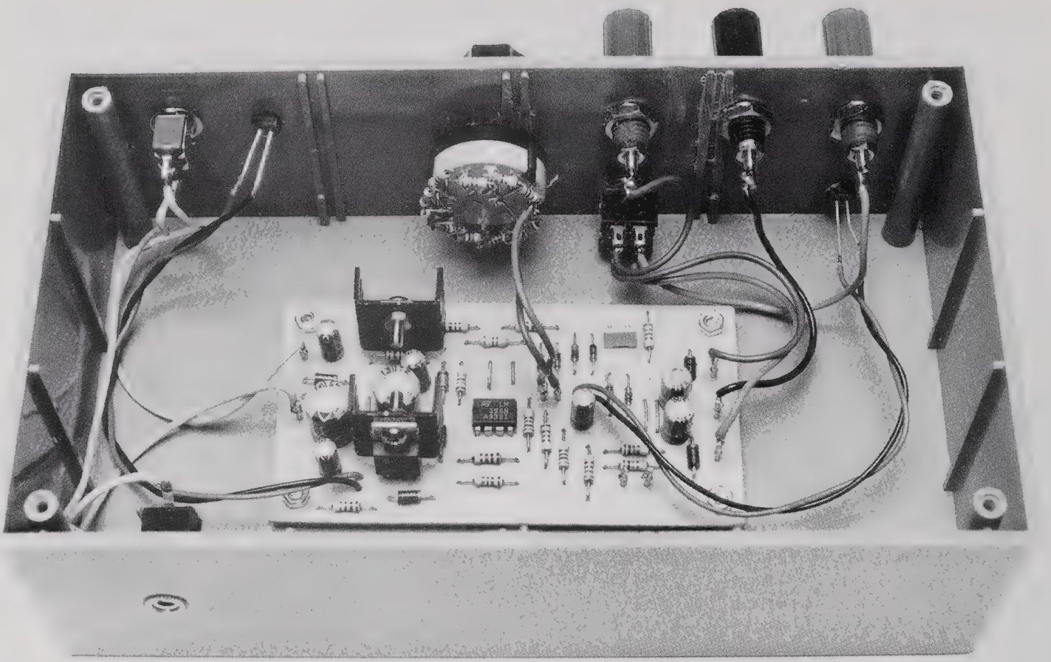
In the case of the positive rail, the LM317 (REG1) does most of the work. Its output voltage is set by the 120Ω and 2.7kΩ resistors on its ADJ terminal and by the resistive divider string associated with switch S3. These components form the feedback network around the regulator IC.

Basically, switch S3 sets the output voltage from REG1 by setting the resistance between the ADJ terminal and the 0V rail. When the ADJ terminal is connected to 0V, the output voltage is +1.25V. This voltage can then by

Fig.2 (right): the circuit uses two adjustable 3-terminal regulators (REG1 & REG2) to provide the positive & negative supply rails. IC1a inverts the control voltage applied to the ADJ terminal of REG1 to drive REG2, while IC1b drives D9-D12 & LED 2 to provide dropout indication.


LOAD
S2a
+V
0V
S2b
-V
R1
R2
M1
+
-
LED2
DROPOUT
4x1N914
D9-D12
1k
7
IC1b
4.7M
5
6
+
-
D6
1N4004
100
25VW
D8
D7
2x1N914
0.1
3.3k
3.3k
D5
1N4004
S3
1.25V
1.5V
3V
4.5V
5V
6V
7.5V
9V
12V
13.5V
15V
120Ω
27Ω
150Ω
180Ω
56Ω
150Ω
220Ω
270Ω
680Ω
470Ω
560Ω
100
25VW
120Ω
OUT
LM337
REG2
ADJ
IN
D4
1N4004
1
1k
1
2.7k
1
1
D3
1N4004
REG1
LM317
IN
OUT
ADJ
+15V
8
IC1a
LM358
4
-15V
3
2
22k
47k
47k
+15V
-15V
330Ω
330Ω
ZD1
15V
ZD2
15V
D1
1N4004
470
25VW
470
25VW
POWER
S1
FROM
16VAC
PLUG-PACK
D2
1N4004
1k
POWER
LED1
LM337
A I O
LM317
A O I
A
K

BEGINNER'S POWER SUPPLY



This is the view inside the prototype. Note the two small heatsinks fitted to the two 3-terminal regulators. Take care to ensure that the regulators are correctly oriented – each device is installed with its metal tab towards the centre of the PC board.

stepped up to a maximum of +15V by using S3 to progressively switch in additional resistors in the string.

The 1μF capacitor between the ADJ pin and ground ensures that any residual noise from the mains is kept to a minimum. Finally, the output voltage from REG1 is filtered by a 100μF electrolytic capacitor and fed to the load via switch S2a.

Negative regulation

The negative regulator (REG2) works in a similar manner to REG1. It's made to track the positive rail by using IC1a to provide a mirror of the voltage on the ADJ terminal of REG1. For example, if the ADJ voltage of REG1 is at 10.75V (to produce a 12V output), then IC1a will act to produce -10.75V on the ADJ terminal of REG2.

This is achieved by connecting IC1a as a unity gain inverting amplifier. Its inverting input (pin 2) is fed from the ADJ terminal of REG1 via a 47kΩ resistor, while the associated 47kΩ feedback resistor sets the gain to -1. The non-inverting input is biased to 0V via a 22kΩ resistor to ensure minimum output offset.

The output of IC1a drives the ADJ terminal of REG2 via a 1kΩ resistor. This 1kΩ resistor is inside the feedback loop and is there so IC1a can actually drive the ADJ terminal to the maximum required value of -13.75V (when the output voltage is set to ±15V). This is outside the operating range of the LM358 because its supply rails are ±15V. The result of all this is that the negative output voltage of REG2 tracks the positive output voltage of REG1.

The ±15V supply rails for IC1 are produced by zener diodes ZD1 and ZD2, while LED1 provides power indication. Diodes D3, D4, D5 and D6 protect the regulators from any reverse voltages which may be generated by capacitive or inductive loads connected across the outputs.

Dropout detection

When the regulators are working as intended, the ripple voltage superimposed on the DC rails will be very low. However, if the current drain is higher than the regulators can supply while still maintaining about 2V between their IN and OUT terminals, the ripple voltage will suddenly become quite high. At this point, the output voltage will fall quite rapidly if even more current is called for and the ripple will go even higher.

What this means of course is that the power supply is unable to provide sufficient current to the load and is dropping out of regulation. This undesirable condition is indicated by the dropout indicator circuit and this is based on IC1b and diodes D9-D12.

IC1b is connected as an inverting amplifier with a high gain, as determined by the ratio of the 4.7MΩ feedback resistor to the impedance of the 0.1μF input capacitor and the 3.3kΩ resistors which monitor the positive and negative supply rails. The two back-to-back diodes, D7 & D8, limit the maximum input signal to ±0.7V.

When ever either regulator drops out of regulation (eg, if an output is shorted to ground), the ripple output increases greatly. Because it operates with such high gain, IC1b squares up this signal to produce a square-wave output at pin 7. This output drives a

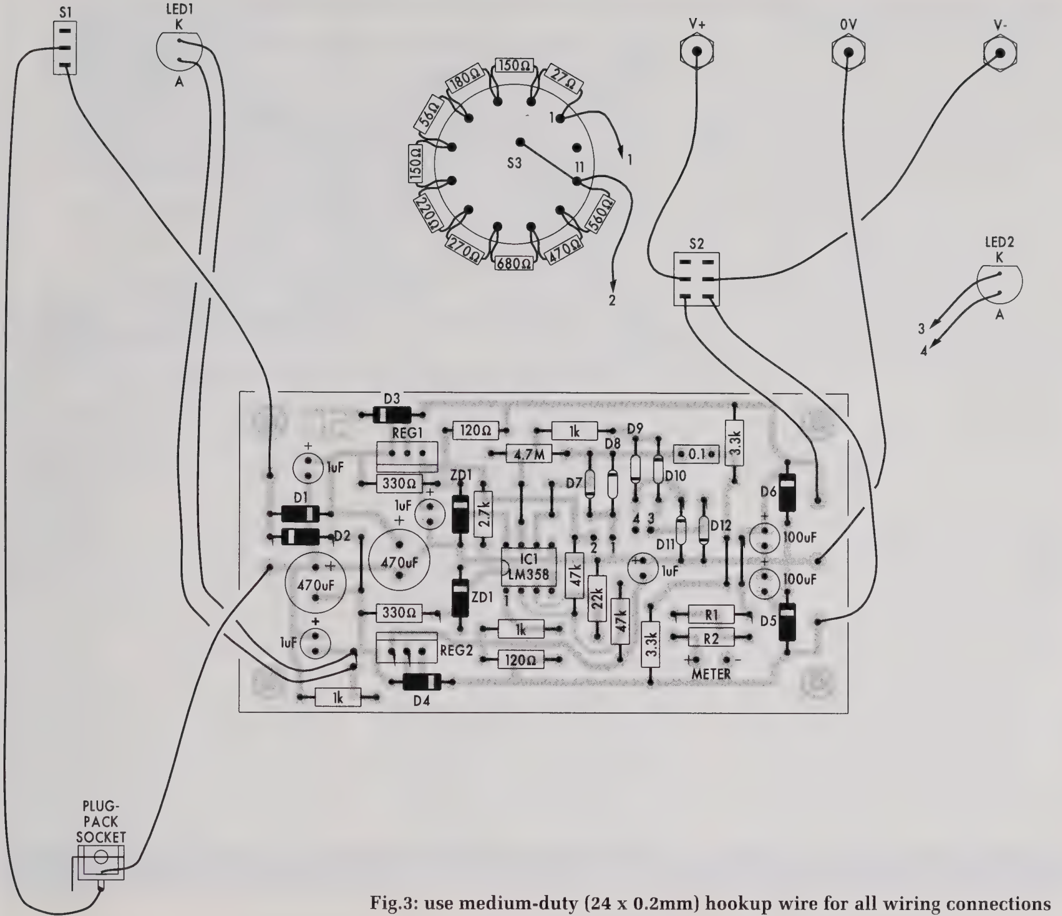

S1
LED1
K
A
V+
0V
V-
150Ω
180Ω
27Ω
56Ω
1
S3
11
1
150Ω
220Ω
560Ω
270Ω
680Ω
470Ω
2
S2
LED2
K
A
3
4
D3
REG1
120Ω
1k
D9
D8
3.3k
4.7M
0.1
1uF
330Ω
ZD1
D7
D10
D6
D1
1uF
2.7k
4 3
D11
D12
100uF
D2
470uF
IC1
LM358
1
2
47k
1uF
100uF
470uF
ZD1
22k
47k
330Ω
R1
D5
1uF
1k
3.3k
R2
REG2
120Ω
METER
1k
D4
PLUG-
PACK
SOCKET

Fig.3: use medium-duty (24 x 0.2mm) hookup wire for all wiring connections & take care to ensure that switch S3 is wired exactly as shown. Resistors R1 & R2 can be left out of circuit if you don't intend installing an output meter.

bridge rectifier consisting of D9-D12 via a 1kΩ current limiting resistor.

The bridge rectifier in turn drives LED 2 and this begins to glow when the ripple at one of the regulator outputs exceeds about 4mV peak-to-peak. By the time the ripple reaches 19mV p-p, the LED is fully alight.

An optional metering circuit is also shown on Fig.2, although we haven't included it in the prototype (the appropriate connection points are on the PC board). All you have to do is calculate what resistance should be added in series with the meter to give a full-scale reading at 30V.

For example, if you have a 0-1mA meter movement, then by Ohm's Law R = V/I = 30/.001 = 30kΩ. Making R1 = 27kΩ and R2 = 2.7kΩ will be near enough, especially when the internal impedance of the meter is taken into consideration.

Construction

All of the components for the Beginner's Power Supply are installed on PC board coded 04110941 and measuring 102 x 57mm. Before commencing construction, check the board carefully against Fig.4 for any shorts or breaks in the tracks. If you find any, use a dash of solder or a small artwork knife where appropriate to fix the problem.

Fig.3 shows the parts layout on the PC board. Start by installing PC stakes at the external wiring points, followed by the wire links, resistors, diodes, capacitors and ICs. Make sure that all polarised parts are correctly oriented and check the resistor values on your multimeter before mounting them on the board. Table 1 shows the resistor colour codes.

Note that diodes D1-D6 are all 1N4004 types, while the remaining diodes are the smaller 1N914 types. Pin 1 of the IC is adjacent to a small notch or dot in one end of the plastic body.

The metal tabs of the two 3-terminal regulators must be oriented exactly as shown on Fig.3; ie, the metal tab of each device goes towards the centre of the board. Do not confuse these two regulators – REG1 is an LM317 type while REG2 is an LM337. Once mounted, they can be fitted with small finned heatsinks to aid cooling.

After the board assembly has been completed, you can install the resistors around switch S3. As supplied, this switch will be a 12-position type. It is easily converted to an 11-position type by lifting the locking ring at the front of the switch bush and rotating it to position 11. This done, solder the resistors to the switch terminals exactly as shown on Fig.3, starting at terminal 1 and continuing in an anticlockwise direction to terminal 11 (note: in most cases, the terminal numbers are marked on the back of the switch).

If you have a switch that doesn't have the terminals marked, here's an easy way to find terminal 1. All you have to do is rotate the switch fully anticlockwise, then use your multimeter to find which terminal is now connected to the wiper. This will be terminal 1 and you can begin by soldering the 27Ω resistor to it. The remaining resistors can then be installed exactly as shown.

Check the resistor values carefully as they are mounted. If you make a mistake, then one or more of the voltage ranges will be wrong. It's also a good idea to trim the resistor leads back as you go so that you don't end up with a tangled mess. Don't forget the wire link between the switch wiper (near the centre) and terminal 11.

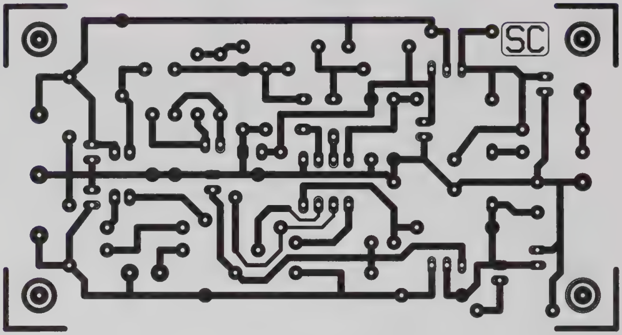


Fig.4: this is the full-size etching pattern for the PC board

The Beginner's Power Supply is designed to fit into a plastic zippy case measuring 198 x 113 x 62mm. The front panel is actually one of the long sides of the case, while the PC board is mounted on the bottom of the case. The whole unit is then turned upside down so that the lid becomes the base.

The first step is to attach the front panel label (bottom nearest the lid), then use this as a drilling template for the front panel items. The PC board can also be used as a template to mark out its four mounting holes, while an additional hole will be required in the rear panel to accept a 3.5mm power socket.

Note that it's best to initially drill all holes to 3mm. These can then be enlarged where necessary using a tapered reamer.

Final assembly

Once the holes have been completed, mount the various items in place. Fig.3 shows where each component should be placed. Note that the range switch (S3) must be oriented so that the pointer on the knob

Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	4.7MΩ	yellow violet green brown	yellow violet black yellow brown
☐	2	47kΩ	yellow violet orange brown	yellow violet black red brown
☐	1	22kΩ	red red orange brown	red red black red brown
☐	2	3.3kΩ	orange orange red brown	orange orange black brown brown
☐	1	2.7kΩ	red violet red brown	red violet black brown brown
☐	3	1kΩ	brown black red brown	brown black black brown brown
☐	1	680Ω	blue grey brown brown	blue grey black black brown
☐	1	560Ω	green blue brown brown	green blue black black brown
☐	1	470Ω	yellow violet brown brown	yellow violet black black brown
☐	2	330Ω	orange orange brown brown	orange orange black black brown
☐	1	270Ω	red violet brown brown	red violet black black brown
☐	1	220Ω	red red brown brown	red red black black brown
☐	1	180Ω	brown grey brown brown	brown grey black black brown
☐	2	150Ω	brown green brown brown	brown green black black brown
☐	2	120Ω	brown red brown brown	brown red black black brown
☐	1	56Ω	green blue black brown	green blue black gold brown
☐	1	27Ω	red violet black brown	red violet black gold brown

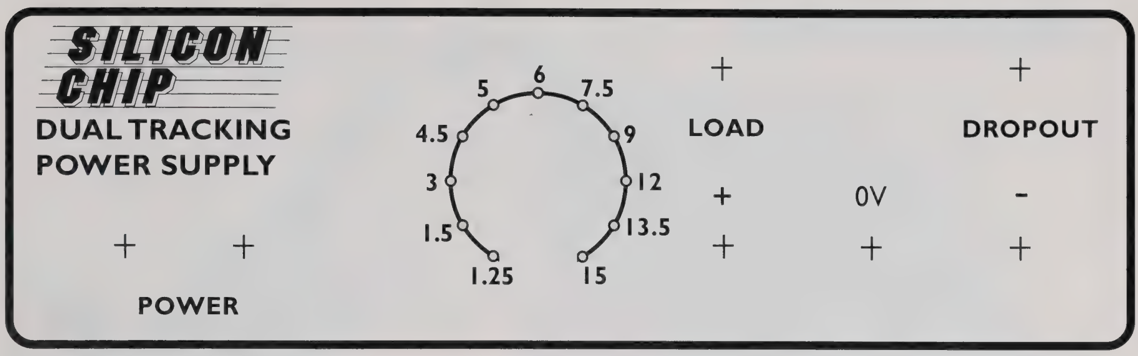

SILICON CHIP
DUAL TRACKING POWER SUPPLY
POWER
+
+
1.25
1.5
3
4.5
5
6
7.5
9
12
13.5
15
LOAD
+
+
+
0V
+
DROPOUT
+
-
+

Fig.5: this full-size artwork can be used as a drilling template for the front panel.

aligns with the 1.25V marking on the front panel when the switch is rotated fully anticlockwise.

Binding posts are used for the three output terminals. We suggest that you use red for positive, black for 0V and blue for the negative. The PC board is secured in the case using machine screws and nuts, with additional nuts under each corner of the board acting as spacers.

The wiring can now be completed as shown in Fig.3. It's a good idea to use different coloured wire for each section, as this will make it easier to check your wiring later on.

Take care with the orientation of the LEDs – the anode lead is always the longer of the two and the cathode will be adjacent to the flat edge on the LED bevel.

Testing

Now for the smoke test. Connect a 16VAC 1A plugpack supply, switch on and use your multimeter to check the voltage between the "+" and "0V" terminals for each switch position. In each case, the measured voltage should correspond to the switch position. The negative rail can then be checked in similar fashion; ie, by connecting the multimeter between the "-" and "0V" terminals.

If everything checks out, the power supply is ready for use. If you strike problems, check the supply rails to the 3-terminal regulators and to IC1. You should find +20V on the IN terminal of REG1, -20V on the IN terminal of REG2, +15V on pin 8 of IC1, and -15V on pin 4 of IC1. If any of these voltages are incorrect, switch off and check D1, D2, ZD1 and ZD2 as appropriate.

If the measured output voltages don't correspond to the switch settings, check the resistor string around S3. You may have some of the resistors in the wrong positions.

Additional heatsinking

As the unit stands, the output current capability is limited by the modest amount of heatsinking. That's because the two 3-terminal regulators have inbuilt thermal overload protection which means that they automatically throttle back when they start to get too hot.

As an option, you can slightly increase the output current capability by increasing the heatsinking. This additional heatsinking can be obtained by substituting an aluminium lid for the plastic lid of the case. The two regulators are then bolted to the lid using TO-220 isolating kits (ie, a mica washer and insulating bush) to provide electrical isolation and their leads connected to the PC board via flying leads. **SC**

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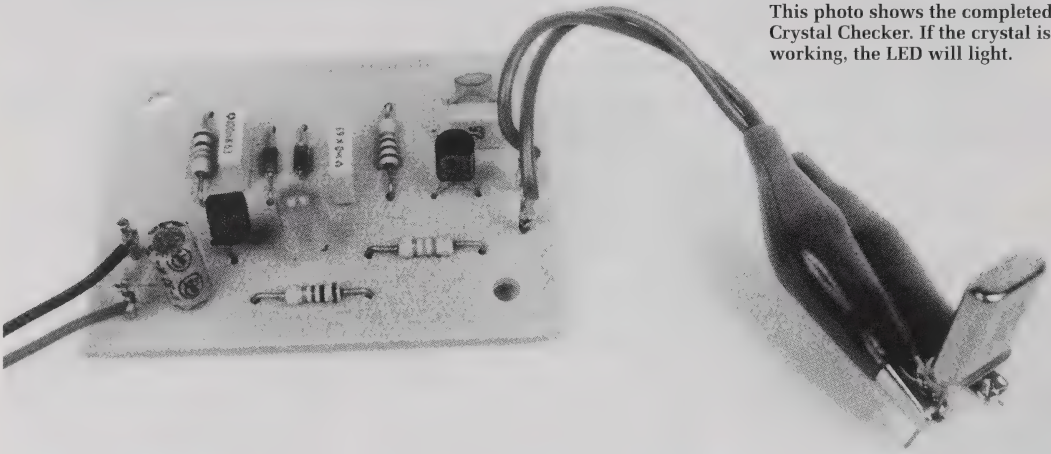


This photo shows the completed Crystal Checker. If the crystal is working, the LED will light.

A Simple Go/No-Go Crystal Checker

This simple circuit will help you sort through that pile of crystals lying on your workbench. If the crystal works, the LED lights. Best of all, it can use parts which you probably already have in your junkbox.

If you've had a go at building any RF projects in the past you'll probably have a couple or maybe quite a few crystals lying around. Crystals are quite fragile components because of their construction. Unlike a resistor or capacitor, if you drop one on the ground from a decent height, it's a 50-50 bet whether it will work again.

Testing them is not a breeze either. You just can't take out your trusty multimeter and plug the crystal in. In fact, the only real way is to try it in an oscillator circuit. And that's exactly what this little Crystal Checker does. The crystal is placed in the feedback network of a transistor oscillator. If it oscillates, meaning that the crystal works, a LED lights up. If the crystal doesn't work, the LED stays off. You can't get much simpler than that.

Note that if you have overtone crystals, the circuit will not tell you whether or not the crystal is operating at the designated frequency, just whether or not it will oscillate at its fundamental frequency.

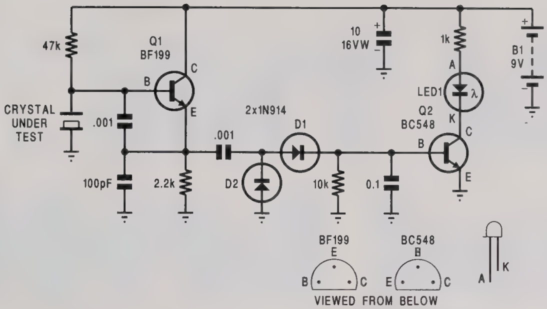
Circuit description

Let's take a look at the circuit in Fig.1. As you can see, there are only two transistors, a couple of diodes, a LED and a few other components. Q1 is a BF199 RF transistor and with its associated components forms an untuned Colpitts oscillator. The crystal forms the main element of the circuit. Positive feedback comes from the emitter through the .001μF capacitor back to the crystal and base.

If the crystal works, the circuit will begin oscillating immediately and a waveform will appear at the emitter of Q1. If you look at this on your oscilloscope, you could expect to see a rough sinewave with and an amplitude of about 2V peak-to-peak, depending on the frequency.

Diodes D1 and D2 rectify the signal from the emitter of Q1 and the resulting DC voltage is fed to the base of transistor Q2. Once this voltage exceeds 0.6V, transistor Q2 turns on and lights LED 1. As soon as the crystal is removed, the circuit stops oscillating and the LED goes out.

As a point of interest, if the crystals you have are less than 10MHz, then you could probably get away with a BC548 for Q1. The BC548-series transistors have a high F_T (gain-bandwidth product) of about 100MHz or so but they don't tend to work well in oscillator circuits above about 10MHz. FM microphones often get away with a BC548 but the output at the required 100MHz or so is quite low – in the



SIMPLE GO/NO-GO CRYSTAL CHECKER

Fig.1: the circuit of the Crystal Checker is shown with a BF199 for Q1 but a BC548 will work with many crystals under 10MHz.

order of millivolts which is too low for our application. Below 10MHz, they work quite well with a good output voltage. Why not try one out and see what you get. You can't damage the crystal and it's always fun to experiment!

Power is supplied by a 9V battery which is bypassed by a 10μF electrolytic capacitor. We haven't specified a power switch mainly for the reason that it would double the cost of the parts! Besides, once you've checked all your crystals, you can unclip the battery and use it on something else.

You could also experiment with different supply rails. The circuit should work well with any voltage between 6V and 15V although if you are using a BC548 for Q1 and a supply voltage of less than 9V, it may not like the higher crystal frequencies. Again, experiment and see for yourself! The quiescent current should be around 3mA, pushing up to 6-8mA with the LED on.

Construction

Construction of the Crystal Checker is a snap and shouldn't take you any more than an hour or so. All of the components except the 9V battery fit on a small PC board, coded 04106941, and measuring only 52 x 40mm.

Before you begin any soldering, check the board thoroughly for any shorts or breaks in the copper tracks.

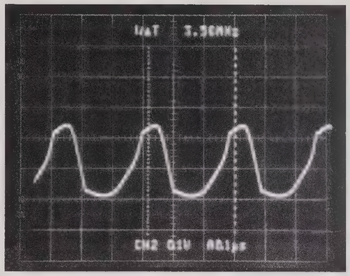


Fig.2: this sample waveform was taken from the emitter of Q1 with the scope probe set to 10:1 division. The crystal was an American TV intercarrier type with a frequency marking of 3.579545MHz. The on-screen measurement shows the frequency as 3.5MHz, well within the accuracy of most oscilloscopes. As you can see, the signal amplitude is about 2.4V peak-peak.

Parts List

1 PC board, code 04106941, 52 x 40mm
1 4 PC stakes
1 9V battery
1 battery clip

Semiconductors
1 BF199 RF NPN transistor (Q1)
1 BC548 NPN transistor (Q2)
2 1N914 signal diodes (D1,D2)
1 5mm green LED (LED1)

Capacitors
1 10μF 16VW electrolytic
1 0.1μF 63VW MKT polyester
2 .001μF 63VW MKT polyester
1 100pF ceramic

Resistors (0.25W, 1%)

1 47kΩ	1 2.2kΩ
1 10kΩ	1 1kΩ

These should be repaired with a small artwork knife or a touch of the soldering iron where appropriate.

When you're satisfied that the board is OK, start by installing the resistors and diodes, followed by the capacitors and transistors. Be sure to follow the overlay diagram (Fig.3) carefully, as some of these components are polarised and won't work if you install them the wrong way around.

Finally, solder in the LED and the PC stakes for the battery and the crystal. You might like to make up a pair of short alligator clip leads to connect the crystal – see photo.

Testing

Testing the circuit is pretty much the same as normal use. Find a crystal that you know works, preferably something between 32kHz to 4MHz, pop it in and connect the 9V battery. If the circuit works, you should see the LED light.

If it doesn't work, check that all the components are in their correct locations and check the orientation of the polarised components, such as the LED, transistors and diodes. In addition, check the solder connections for dry joints or shorts between tracks on the PC board. **SC**

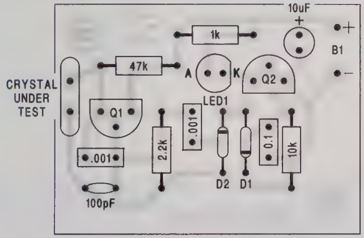


Fig.3: the component layout diagram for the PC board. We suggest connecting a pair of leads with crocodile clips to make connections to the crystal.

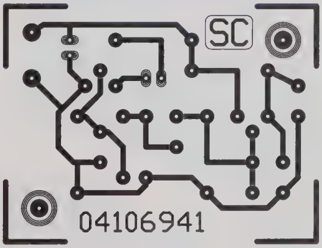


Fig.4: this is the full size artwork for the PC board. Check your board carefully against this pattern before mounting any of the parts.

Build This Sound Level

OFF
ON
SLOW
FAST
PEAK
RESPONSE
SILICON CHIP
SOUND LEVEL METER
C-WEIGHTING
A-WEIGHTING
UNWEIGHTED
FILTER
CONNECT TO MULTIMETER (10mV/dB)

This Sound Level Meter adaptor will measure sound pressure levels from below 20dB up to 120dB with high accuracy. It connects to any standard digital multimeter and has inbuilt filters for A and C-weighting.

Noise can have a huge affect on the quality of our lives. A reliable measuring instrument is a must for those interested in finding out just how much noise is in their environment.

Just how much noise is present at any time is very subjective. If you are confined to a soundproof room for a period of time, even the sound of a pin dropping will seem quite loud. But if you are in a normal home or office environment, the dropping of a pin is likely to be completely inaudible. And even the sounds of people on the telephone or using computers may be completely drowned out if a semi-trailer passes down your street or a jet flies overhead.

The above examples show just how exceptional our ears are in responding to the possible range of sounds in our environment. In fact, we could expect to experience a sound pressure range of about three million to one. Because of this huge range of values sound pressure levels are usually expressed in decibels, a logarithmic ratio where 20dB (decibels) is equivalent to 10:1; 40dB is 100:1 and 60dB is 1000:1, all compared to a reference level. The overall 3,000,000 to 1 range can then be expressed as 130dB (20 log 3,000,000).

Since the dB is a ratio it must be referenced

Main Features

- Connects to any digital multimeter
- Calibration method uses loudspeaker & pink noise source
- A and C weighting plus flat (unweighted) filters
- Slow, Fast and Peak response

By JOHN CLARKE

Meter

to a particular pressure level of 20.4μPa (micro Pascals). Usually, sound pressure levels are quoted as so many dBSPL, indicating that the 0dB reference is 20.4μPa.

On the dBSPL scale, 0dB is virtually inaudible, 30dB might be the sound level in a quiet rural area with no wind while a noisy home kitchen might be 80dB or more. Heavy traffic can easily be 80-90dB while a suburban train in a tunnel can produce 100dB. Electric power tools or pneumatic drills can easily run at 110dB and some can go into the pain level at 120dB.

Measuring SPL

The SILICON CHIP Sound Level Meter is designed to produce accurate readings of sound pressure which are displayed on a digital multimeter. It comprises a handheld case with a short tube supporting the microphone at one end of the unit. Flying leads with banana plugs connect to the multimeter.

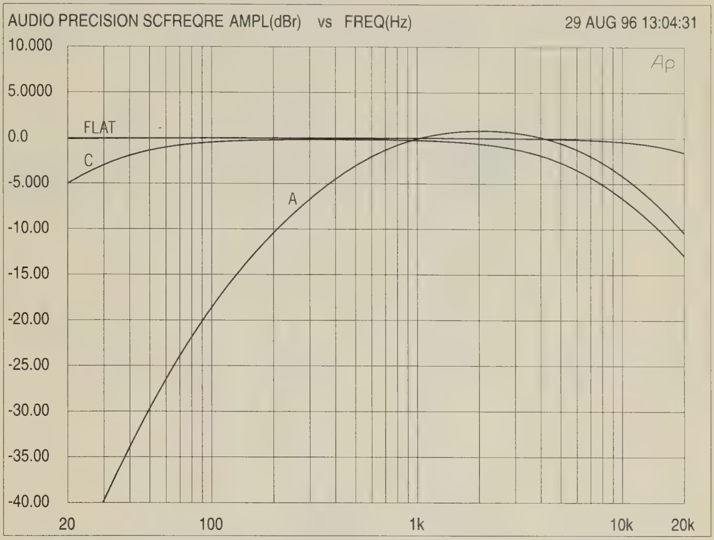


Fig.1: this graph shows the differences between A and C-weighting and flat (unweighted) responses in the Sound Level Meter.

A slide switch provides A-weighting and C-weighting filters to tailor the measurement readings. A-weighting is called for in many measurements to Australian standards although it is not really appropriate for louder sounds where C-weighting or a flat response (unweighted) can give more meaningful results. Fig.1 shows the differences between A and C-weighting and flat (unweighted) responses in the Sound Level Meter.

Slow and fast response times are provided as well, so that sudden noise can be filtered out, if need be.

A "peak detect" facility has also been included which will give an in-

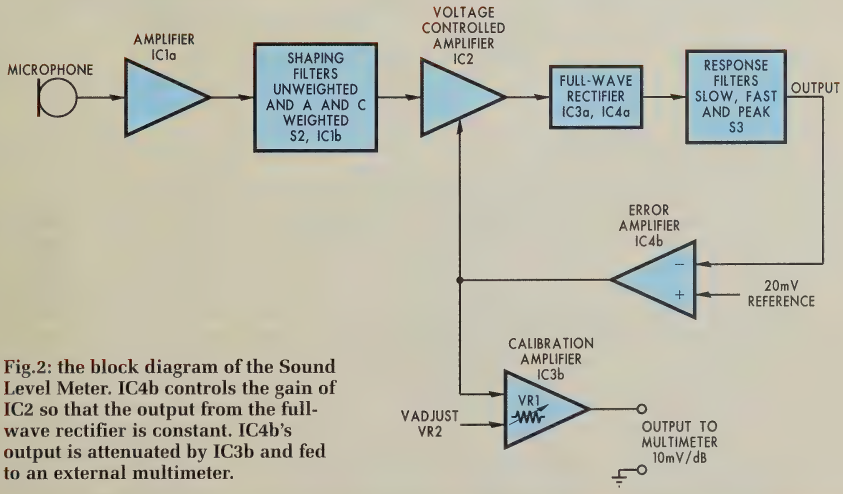

MICROPHONE
AMPLIFIER IC1a
SHAPING FILTERS UNWEIGHTED AND A AND C WEIGHTED S2, IC1b
VOLTAGE CONTROLLED AMPLIFIER IC2
FULL-WAVE RECTIFIER IC3a, IC4a
RESPONSE FILTERS SLOW, FAST AND PEAK S3
OUTPUT
ERROR AMPLIFIER IC4b
−
+
20mV REFERENCE
CALIBRATION AMPLIFIER IC3b
VR1
VADJUST VR2
OUTPUT TO MULTIMETER 10mV/dB

Fig.2: the block diagram of the Sound Level Meter. IC4b controls the gain of IC2 so that the output from the full-wave rectifier is constant. IC4b's output is attenuated by IC3b and fed to an external multimeter.

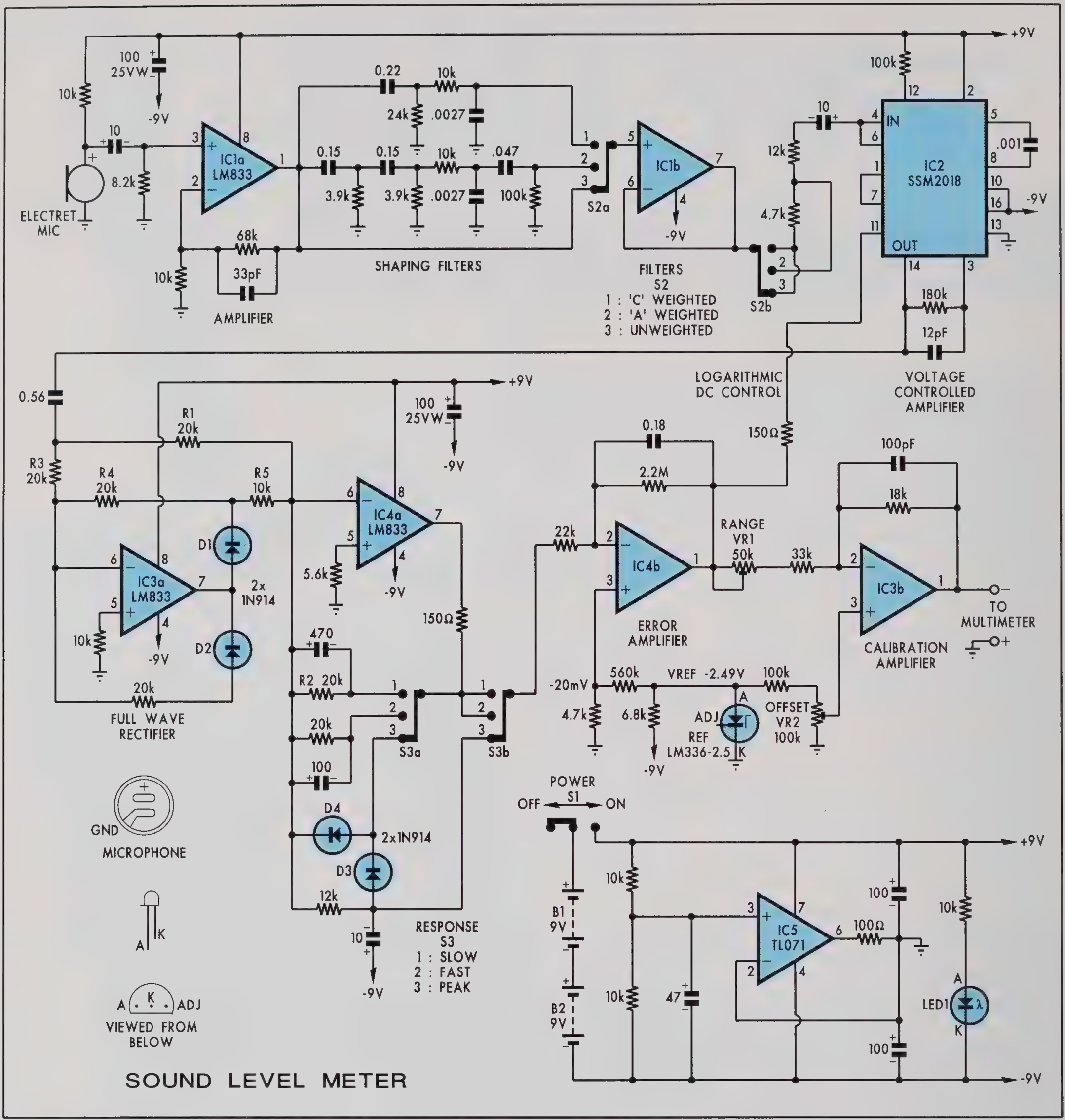

+9V
100 25VW
10k
-9V
10
8.2k
ELECTRET MIC
IC1a LM833
10k
68k
33pF
AMPLIFIER
0.22
10k
24k
.0027
0.15
0.15
10k
.047
3.9k
3.9k
.0027
100k
SHAPING FILTERS
S2a
IC1b
-9V
FILTERS
S2
1 : 'C' WEIGHTED
2 : 'A' WEIGHTED
3 : UNWEIGHTED
12k
4.7k
S2b
10
100k
IN
IC2 SSM2018
OUT
.001
-9V
180k
12pF
VOLTAGE CONTROLLED AMPLIFIER
LOGARITHMIC DC CONTROL
150Ω
0.56
R1 20k
R3 20k
R4 20k
R5 10k
+9V
100 25VW
-9V
IC4a LM833
5.6k
-9V
IC3a LM833
D1
2x 1N914
D2
10k
-9V
20k
FULL WAVE RECTIFIER
150Ω
470
R2 20k
20k
100
S3a
S3b
D4
2x1N914
D3
12k
10
-9V
RESPONSE
S3
1 : SLOW
2 : FAST
3 : PEAK
0.18
2.2M
22k
IC4b
ERROR AMPLIFIER
RANGE VR1 50k
33k
100pF
18k
IC3b
CALIBRATION AMPLIFIER
TO MULTIMETER
-20mV
560k
VREF -2.49V
100k
4.7k
6.8k
-9V
ADJ
REF LM336-2.5
A
K
OFFSET VR2 100k
GND
MICROPHONE
A
K
A
K
ADJ
VIEWED FROM BELOW
POWER
S1
OFF
ON
B1 9V
B2 9V
10k
10k
47
IC5 TL071
100Ω
100
100
10k
LED1
+9V
-9V
SOUND LEVEL METER

Fig.3: apart from the use of a VCA (IC2), an unusual feature of the circuit is the use of IC5 to evenly split the 18V supply. This has been done because the negative rail is subjected to a higher current drain than the negative rail, which would shorten the life of battery B2.

dication of the noise waveform shape. If there is no or little difference between the peak and the fast reading then the noise waveform can be assumed to be relatively sinusoidal. If, however, the peak level is greater than the fast reading, then the noise waveform has a lot of transient bursts. These may result in a low average value as shown on the slow or fast response settings but are easily captured by the peak detect circuitry.

The cost of the Sound Level Meter has been kept low by using a multimeter as the display.

Logarithmic conversion

As already noted, the Sound Level Meter will read from below 20dBSPL to 120dBSPL, a range of 100dB. That's a pretty stiff requirement. The circuit has to provide a direct logarithmic conversion over 100dB, producing an output of 10mV per dB.

In practice, the signal fed to the multimeter ranges from 200mV at 20dB to 1.2V at 120dB. This means that all readings can be made on the 2V range of the multimeter; there is no need to switch ranges.

Fig.2 shows the block diagram of

our sound level meter. Signal from the microphone is amplified by op amp IC1a and then fed to either the A or C-weighting filters which involve switch S2 and op amp IC1b.

IC2 is a voltage-controlled amplifier (VCA) which can either amplify or attenuate the signal from IC1b, depending on the voltage at its control input. This input operates in a logarithmic fashion so that small control voltage changes can produce large variations in the output signal.

IC2's output is full wave rectified by IC3a & IC4a and the rectified signal fed to the Slow, Fast or Peak filters involving switch S3. The resulting DC voltage is compared in error amplifier IC4b against a 20mV reference. IC4b's output then controls the VCA so that it produces a constant output regardless of changes in the microphone signal.

As well as driving the control input of the VCA, IC4b drives op amp IC3b which modifies the signal so that it provides the required 10mV per dB, to drive the external multimeter.

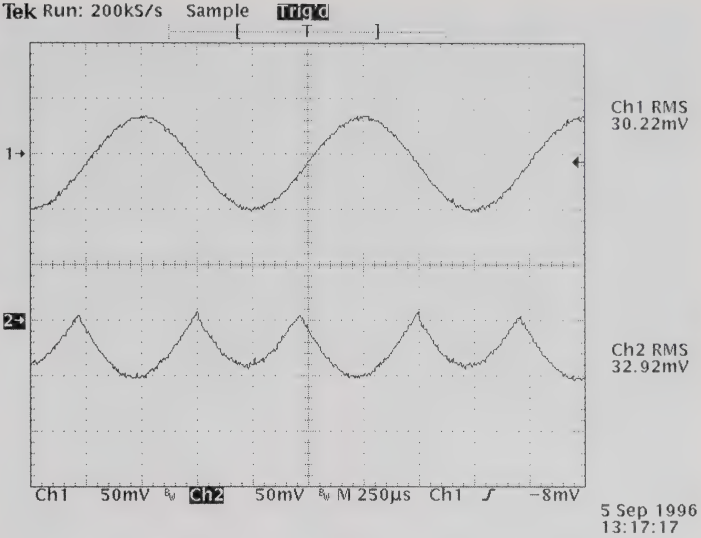


Fig.4: waveforms from the precision full-wave rectifier. The top trace (Ch1) shows the input sinewave while the lower trace (Ch 2) is the rectified version. Note that the RMS values are slightly different due to small offsets in the op amps.

Circuit description

Fig.3 shows the complete circuit for the Sound Level Meter. It uses five ICs, three of which are dual op amps (IC1, IC3 & IC4). IC2 is the VCA, which can be considered as an op amp with a DC gain control. IC5, a TL071 single op amp, is used to accurately split the 18V battery supply; more of that later.

The microphone is an electret type which is biased via a 10kΩ resistor from the +9V supply. Its signal is coupled to op amp IC1a which has a gain of 7.9 (+18dB), as set by the 68kΩ and 10kΩ feedback resistors. This gain has been selected for the specified microphone and will need to be altered if other types are used.

IC1a drives both the C and A-weighting filters. These are selected at positions 1 and 2 of switch S2a respectively. Position 3 selects IC1a's output directly for the flat or unweighted signal mode. IC1b is simply a unity gain amplifier to buffer the filters and prevent loading of the filter signal.

IC1b's output is fed to IC2 via switch S2b and a 10µF coupling capacitor. Note that in positions 1 and 3 of S2b, the 4.7kΩ and 12kΩ resistors are connected in series while for position 2, the 4.7kΩ resistor is bypassed. This allows a 3dB higher gain for IC2 when A-weighting is selected. The gain adjustment is necessary to maintain the same 1kHz signal level applied to IC2 for all positions of switch S2.

IC2 is an Analog Devices voltage-controlled amplifier (VCA). It has a dynamic range of 117dB, .006% distortion at 1kHz and unity gain, and a gain control range of 140dB. The DC control input operates at -30mV per dB gain change. IC2's gain is set by the voltage at pin 11 and the ratio of resistance between pins 3 and 14 and the input at pins 4 & 6.

The 100kΩ resistor between pin 12 and the +9V rail sets the bias level for the output at pin 14. This bias can be selected for class A or B operation. Class A gives lower distortion but slightly higher noise. We opted for class B bias for best noise performance. A .001µF capacitor between pins 5 & 8 compensates the gain control circuitry.

Precision rectifier

IC2 is AC-coupled to the precision full-wave rectifier formed by op amps IC3a & IC4a. For positive signals, IC3a's output goes low to reverse bias diode D1. Positive-going signals are then summed in inverter IC4a via the 20kΩ resistor R1 to produce a negative output at pin 7. The gain is -1. Diode D2 and the 20kΩ series resistor limit the op amp's negative excursion.

For negative signals D1 conducts and IC3a acts as an inverting amplifier with a gain of -1 to sum into IC4a via R5. Negative-going signals are also summed in IC4a via R1. Since the voltages across R1 and R5 are equal but opposite and the value of R5 is exactly half R1, the net result of the sum into IC4a is a negative output with an overall gain of 1.

So for positive signals applied to the full wave rectifier the gain is -1 and for negative signals the gain is 1. Thus IC3a and IC4a form a precision full wave rectifier. The 10kΩ and 5.6kΩ resistors at IC3a's and IC4a's non-inverting inputs minimise any offset voltages in the op amps.

Fig.4 shows the oscilloscope waveform of the precision full wave rectifier. The top trace shows the input sinewave while the lower trace is the rectified version. Note that the RMS values are slightly different due to small offsets in the op amps.

The switched feedback across IC4a provides filtering of the rectified signal as well as gain control. In the 'slow' setting of S3a, the 20kΩ resistor sets the gain and the 470µF capacitor controls the response. Similarly, for the 'fast' setting of S3a, the 100µF capacitor sets the response. In the 'peak' position of S3, diode D3 charges the 10µF capacitor to the peak value

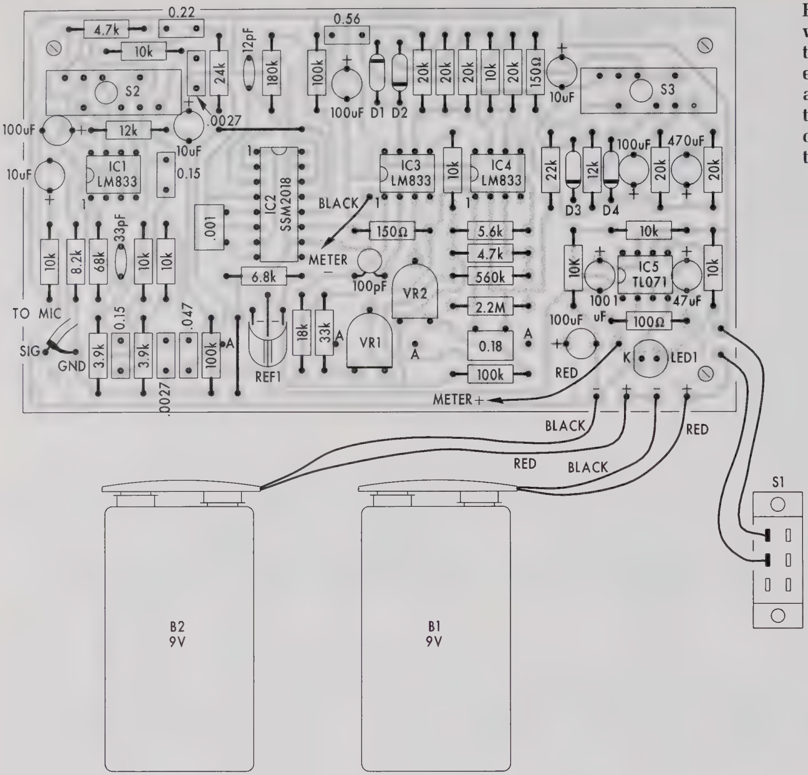

0.22
4.7k
10k
0.56
S2
24k
12pF
180k
100k
100uF
D1
D2
20k
20k
20k
10k
20k
150Ω
10uF
S3
100uF
12k
.0027
10uF
10uF
IC1
LM833
0.15
IC2
SSM2018
IC3
LM833
IC4
LM833
10k
22k
12k
100uF
470uF
20k
20k
D3
D4
BLACK
150Ω
5.6k
4.7k
560k
2.2M
10k
10k
8.2k
68k
33pF
10k
10k
.001
METER –
6.8k
100pF
VR2
IC5
TL071
10K
10k
100
uF
47uF
100Ω
100uF
TO MIC
SIG
GND
3.9k
0.15
3.9k
.047
100k
A
REF1
18k
33k
A
VR1
A
0.18
A
100k
RED
K
LED1
.0027
METER +
BLACK
RED
RED
BLACK
S1
B2
9V
B1
9V

Fig.5: follow this diagram when installing the parts on the PC board and take care to ensure that all polarised parts are correctly oriented. Note that REF1 and a number of capacitors must be laid flat on the PC board (see text).

of the waveform while the 12kΩ resistor sets the gain. This is lower than the 20kΩ value used in the other S3 positions so that the output at the wiper of S3b is the same as for the slow and fast settings when a sinewave is applied.

Error amplifier

The filter signal at the wiper of S3b is monitored with error amplifier IC4b. This has a gain of -100 (ie, it is an inverting amplifier) and compares the rectified signal from switch S3b against the -20mV reference at the non-inverting input, pin 3. IC4b's output drives pin 11 of IC2.

The -20mV reference is derived from the 2.49V reference REF1 via 560kΩ and 4.7kΩ resistors. REF1 is an LM336-2.5 precision reference diode which has facility for a small amount of adjustment although it is not used here.

REF1 is also used to provide a calibration offset for op amp IC3b. IC3b attenuates the logarithmic DC control voltage for IC2 to convert its nominal 30mV/dB calibration to 10mV/dB. VR1 allows precise adjustment of this calibration, providing a divide by 4.6 to 1.8 range. VR2 is the offset adjustment.

The big picture

If, after reading the circuit description so far, you are unclear about its operation, do not despair. Let's summarise what really happens. Op amp IC4b, the error amplifier, is really the heart of the circuit. It continually adjusts the control voltage fed to IC2 so that the negative DC voltage fed from the wiper of S3b to its pin 2 is always very close to the -20mV at its pin 3.

Capacitor Codes

	Value	IEC	EIA
☐	0.56µF	560n	564
☐	0.22µF	220n	224
☐	0.18µF	180n	184
☐	0.15µF	150n	154
☐	.047µF	47n	473
☐	.0027µF	2n7	272
☐	.001µF	1n	102
☐	100pF	100p	101
☐	33pF	33p	33
☐	12pF	12p	12

In fact, VCA IC2 does not really operate as an amplifier for most of the time. For example, when a signal of 120dBSPL is fed to the microphone, the output of IC1a and IC1b is close to clipping; ie, around 14V peak-to-peak or 5V RMS. This is heavily attenuated by IC2 so that around 30mV RMS (see Fig.4) is applied to the input of the precision rectifier, IC3a.

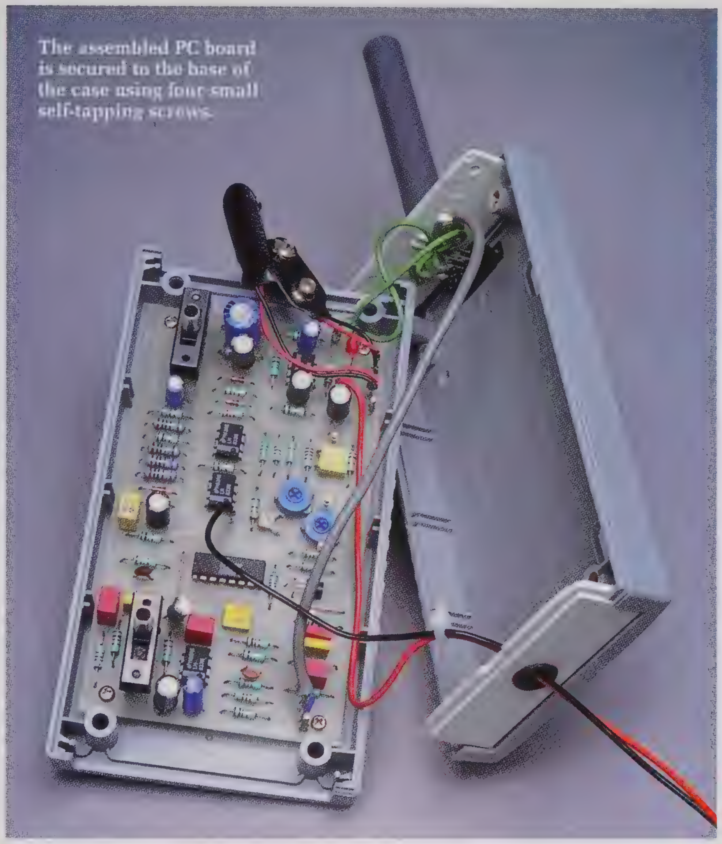
Actually, it is only for signals of around 20mV or less from IC1b that the circuit involving IC2 has any gain; the rest of the time it is attenuating and the actual degree of attenuation depends on the size of the signal coming from IC1a. Typically, the control voltage delivered by IC4b ranges from about +3V, corresponding to maximum attenuation in this circuit, to about -1V, corresponding to maximum gain.

Hence, IC4b makes sure that its two inputs are very similar, and in doing so, it produces a control voltage which happens to be 30mV/dB. This is then further attenuated by IC3b to produce an output of 10mV/dB which can be read out as a measure of the sound pressure level. Looked at this way, the output voltage read by the external multimeter is almost just a byproduct of the overall circuit operation.

Battery supply

Two 9V batteries in series provide an 18V supply. The 18V is divided using two series connected 10kΩ resistors, to produce a 0V reference and this is buffered by op amp IC5. IC5's output feeds a 100Ω resistor and two 100μF capacitors. These decouple the op amp's output and ensure that it has a very low output impedance at all frequencies of interest. The result is a dual-tracking supply which is nominally ±9V.

Now why go to all that trouble when we could have used the midpoint of the two 9V batteries to do the same thing? The reason is that there is more current drain from the negative rail in this circuit and so the negative 9V battery would normally be discharged faster than the positive 9V battery. This would be a problem because the circuit require more negative output swing.


The assembled PC board is secured to the base of the case using four small self-tapping screws.

Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	2.2MΩ	red red green brown	red red black yellow brown
☐	1	560kΩ	green blue yellow brown	green blue black orange brown
☐	1	180kΩ	brown grey yellow brown	brown grey black orange brown
☐	3	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	68kΩ	blue grey orange brown	blue grey black red brown
☐	1	33kΩ	orange orange orange brown	orange orange black red brown
☐	1	22kΩ	red red orange brown	red red black red brown
☐	1	24kΩ	red yellow orange brown	red yellow black red brown
☐	6	20kΩ	red black orange brown	red black black red brown
☐	1	18kΩ	brown grey orange brown	brown grey black red brown
☐	2	12kΩ	brown red orange brown	brown red black red brown
☐	9	10kΩ	brown black orange brown	brown black black red brown
☐	1	8.2kΩ	grey red red brown	grey red black brown brown
☐	1	6.8kΩ	blue grey red brown	blue grey black brown brown
☐	1	5.6kΩ	green blue red brown	green blue black brown brown
☐	2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	2	3.9kΩ	orange white red brown	orange white black brown brown
☐	2	150Ω	brown green brown brown	brown green black black brown
☐	1	100Ω	brown black brown brown	brown black black black brown

This battery holder was made by soldering several pieces of double-sided PC board material together. The three smaller pieces fit into the integral slots moulded into the lid of the plastic case.

By using the op amp split supply method, the current drain from the two 9V batteries must always be the same and the battery life will be extended. For the same reason, LED1 is connected across the full 18V supply via a 10kΩ resistor.

Construction

The SILICON CHIP Sound Level Meter is housed in a plastic case measuring 150 x 80 x 30mm and uses a PC board coded 04312961 and measuring 67 x 120mm. The microphone is held inside a copper tube which protrudes from the front of the case. This is done to prevent sound reflections from the case from upsetting the reading.

Fig.5 shows the component layout for the PC board. You can start construction by checking the PC board for any shorts or breaks in the copper tracks. Repair any faults before assembly of components. Begin by inserting the two links and all the resistors. The accompanying table can be used as a guide for the resistor colour codes. Alternatively, use your multimeter to check each resistor as it is installed.

Next, insert and solder in the PC stakes. These are located at all external wiring points, the 'A' positions and for the eight switch terminal locations for S2 and S3.

Next, the ICs can be inserted and soldered in. Take care with the orientation of each and make sure that IC5 is the TL071 (or LF351). Diodes D1-D4 can now be inserted, taking care to ensure that they are also correctly oriented. Switches S2 and S3 can be mounted by soldering their pins to the top of the PC stakes.

REF1 is mounted on its side as shown in Fig.5, to allow room for the battery to lie on top of the PC board. For the same reason, the .001μF capacitor near IC2, the 0.18μF capacitor near VR2 and the 100pF capacitor near VR1 should be inserted so that they lie flat on the board.

The electrolytic capacitors must be oriented as shown. Insert and solder LED1 at the end of its leads to allow it to protrude through the front panel when assembled. Insert trimpots VR1 and VR2 and cut the 'A' PC stakes slightly higher than the trimpot height. This will prevent the batteries pressing on the trimpots and altering the set values.

Now fit the assembled PC board into the base of the case and secure it with four small self-tapping screws. Wire up the 9V battery clips and multimeter leads as shown. Prepare the two wires for switch S1.

Fit the front panel label to the lid of the case and drill and file out the holes for the switches and LED. Attach S1 with the screws and connect its wiring.

The rear end panel can be drilled to accept a small grommet. Pass the multimeter leads through the grommetted hole and attach the banana plugs to it.

Microphone mounting

An 80mm length of 12.7mm copper tube is soldered to a 12 x 30mm piece of 1mm thick copper sheet (or PC board). The copper sheet becomes a flange for easy attachment to the front end piece of the box. Drill holes in the flange and front end plate to allow it

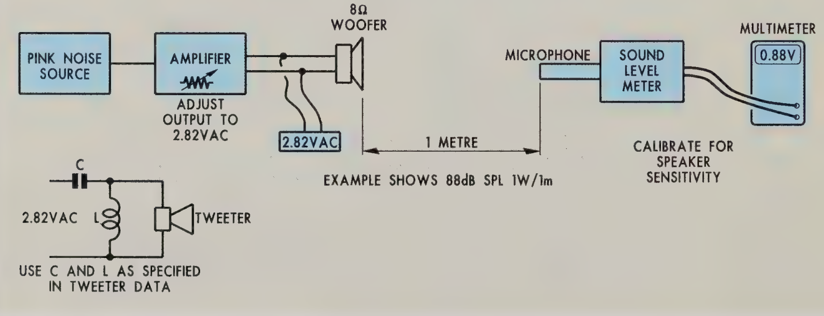


Fig.6: this is the set up used for calibrating the Sound Level Meter. It relies on using a speaker of known sensitivity. Most manufacturers quote sensitivity figures for their loudspeakers.

Performance

'A' response	-18dB at 100Hz, -10dB at 20kHz (see Fig.1)
'C' response	-5dB at 20Hz, -13dB at 20kHz (see Fig.1)
Overall flat response (input versus multimeter reading)	-3dB at 28Hz and 50kHz
Log conversion accuracy at multimeter output	<0.5dB over a 100dB range from 0.550V RMS to 5.5µV input level
Temperature stability	<10mV (1dB) change per 30°C
Slow response time constant	9.4 seconds
Fast response time constant	2 seconds
Peak response	1.5ms attack; 120ms decay
Power	12-18V at 32mA

Microphone Performance (ECM-60P A version)

Sensitivity	-56dB ±3dB with respect to 0dB+1V/µbar @ 1kHz
Microphone response	within ±3dB from 50Hz to 3kHz and ±6dB from 3kHz to 8kHz. Above 8kHz and below 50Hz unspecified.
Maximum SPL	120dB

Note: filter responses measured at VCA output with control input (pin 11) grounded.

to be secured with two screws and nuts. Also drill a hole central to the flange and end plate for the shielded cable to pass through the tube. The tube and flange can be painted if desired.

Connect the microphone using shielded cable and attach some heatshrink tubing around its body. Shrink the tubing down with a hot air gun and insert the wire and microphone into the tube. Leave the microphone flush with the end of the tube. The flange can be attached to the end plate of the case with the screws and nuts. The shielded cable is clamped with a solder lug attached to one of the screws.

The batteries are held in place on the lid of the case using three pieces of double-sided PC board (73 x 5mm) which are inserted in the integral slots. Two pieces of double sided PC board, measuring 30 x 15mm, are soldered in place between the transverse pieces so that they provide a snug fit for the battery and clip assemblies. Check that the lid will fit onto the base of the case.

Voltage checks

Switch on and connect the red multimeter lead from the Sound Level Meter to the common input of the multimeter and then measure voltages on the circuit with the other lead of the multimeter. Check that there is +9V at pin 8 of IC1, IC3 and IC4; at pin 7 of IC5; and at pin 2 of IC2. There should be -9V at pin 4 of IC1, IC3, IC4 & IC5 and at pins 10 & 16 of IC2.

REF1 should have -2.49V at its anode and pin 3 of IC4b should be -20mV. LED1 should also be lit.

Connect both output leads from the sound level meter to the multimeter.

Calibration

Calibration is done in two steps and a pink noise source is required for both steps. A suitable pink noise source is described in this book (see page 91) and we assume that you will also build that or have access to an equivalent source.

First, connect the pink noise source to the electret microphone input of the sound level meter. Select 0dB on the pink noise source (equivalent to 60mV RMS) and adjust trimpot VR2 for a reading on the multimeter of 1V DC. Now switch to -60dB on the pink noise source and check that the multimeter reading is 400mV. If it is greater than 400mV, rotate VR1 slightly clockwise.

Conversely, if the multimeter reading is less than 400mV, rotate VR1 slightly anticlockwise. Now measure the difference again with the 0dB/-60dB switch. You will note that the reading will now not be 1V for the 0dB setting. However, what we are looking for is a 600mV change between the 0dB and -60dB pink noise level settings (ie, 10mV per dB). After some repeat adjustments of VR1 it should be possible to obtain close to 600mV variation between the 0dB and -60dB settings.

Calibration now only requires the

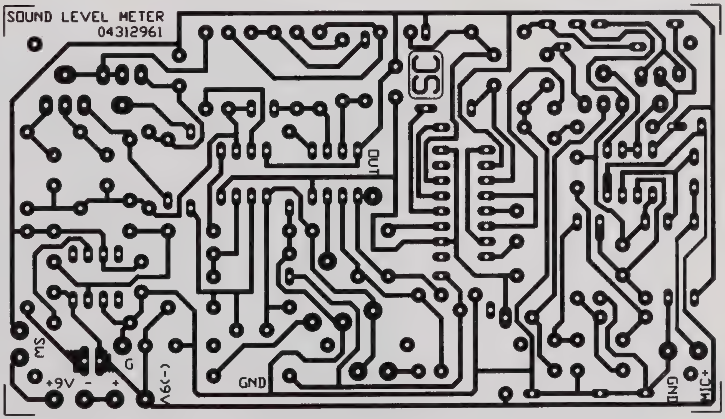


Fig.7: check your etched PC board against this full-size artwork before installing any of the parts.

offset adjustment trimpot VR2 to be set. This is done using the setup shown in Fig.6.

You will need an amplifier, the pink noise source and a woofer or tweeter with known sensitivity. All manufacturers of loudspeakers provide a sensitivity rating for their units and these are specified as a dBSPL when driven at 1W and at 1m on axis. Note that if you use a tweeter, the manufacturer's specified filter should be used when making the measurement.

For example, a loudspeaker may be rated at 88dB when mounted on a baffle and driven from a 2.828V AC source at a distance of 1m. The loudspeaker impedance is 8Ω. Note that 2.828V into 8Ω is equivalent to 1W.

Use your multimeter to measure the voltage applied to the loudspeaker and set the amplifier's volume control to deliver 2.828V AC for an 8Ω system and 2V AC for a 4Ω speaker. Be sure to set your amplifier's tone controls to the flat settings (ie, centred or switched off) and make sure that the loudness switch is off.

Now connect the multimeter to the sound level meter (with the unweighted and slow settings selected) and with the microphone at 1-metre and on axis to the speaker. Adjust trimpot VR2 to obtain the loudspeaker sensitivity. For our 88dB example, the multimeter should read 0.88V or 880mV DC.

Alternatively, if you have a calibrated sound level meter, adjust VR2 for the same readings. Make sure that both sound level meters are set with the same filtering and responses. **SC**

Parts List

1 plastic case, 150 x 80 x 30mm
1 PC board, code 04312961, 67 x 120mm
1 front panel label, 75 x 144mm
1 ECM-60P type A electret microphone (sens. -56dB with respect to 1V/1μbar at 1kHz)
3 pieces of double sided PC board, 73 x 5mm
2 pieces of double sided PC board, 30 x 15mm
1 DPDT slider switch and mounting screws (S1)
2 DP3P slider switches (S2,S3)
1 50kΩ horizontal trimpot (VR1)
1 100kΩ horizontal trimpot (VR2)
2 9V battery snaps
2 9V batteries
1 black banana plug
1 red banana plug
1 250mm length of shielded cable
1 500mm length of black hookup wire
1 500mm length of red hookup wire
1 50mm length of 0.8mm tinned copper wire
30 PC stakes
2 3mm x 10 screws and nuts
4 small self-tapping screws (to secure PC board)
1 solder lug
1 small rubber grommet
1 small cable tie

Semiconductors

3 LM833 dual op amps (IC1,IC3,IC4)
1 SSM2018P voltage controlled amplifier (IC2)
1 TL071, LF351 op amp (IC5)
4 1N914 signal diodes (D1-D4)
1 LM336-2.5 2.5V reference (REF1)
1 3mm red LED (LED1)

Capacitors

1 470μF 16VW PC electrolytic
5 100μF 25VW PC electrolytic
1 47μF 16VW PC electrolytic
3 10μF 16VW PC electrolytic
1 0.56μF MKT polyester
1 0.22μF MKT polyester
1 0.18μF MKT polyester
2 0.15μF MKT polyester
1 .047μF MKT polyester
2 .0027μF MKT polyester
1 .001μF MKT polyester
1 100pF ceramic
1 33pF ceramic
1 12pF ceramic

Resistors (0.25W 1%)

1 2.2MΩ
1 560kΩ
1 180kΩ
3 100kΩ
1 68kΩ
1 33kΩ
1 24kΩ
1 22kΩ
6 20kΩ
1 18kΩ
2 12kΩ
9 10kΩ
1 8.2kΩ
1 6.8kΩ
1 5.6kΩ
2 4.7kΩ
2 3.9kΩ
2 150Ω
1 100Ω

Miscellaneous

12mm diameter heatshrink tubing, solder.

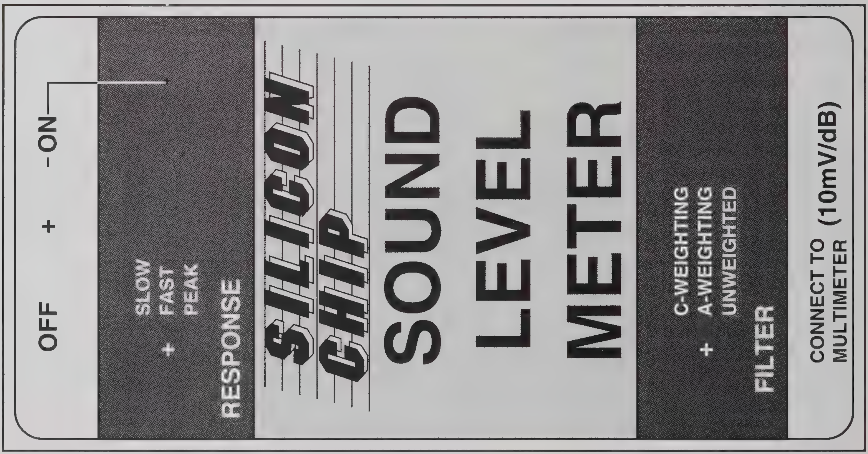
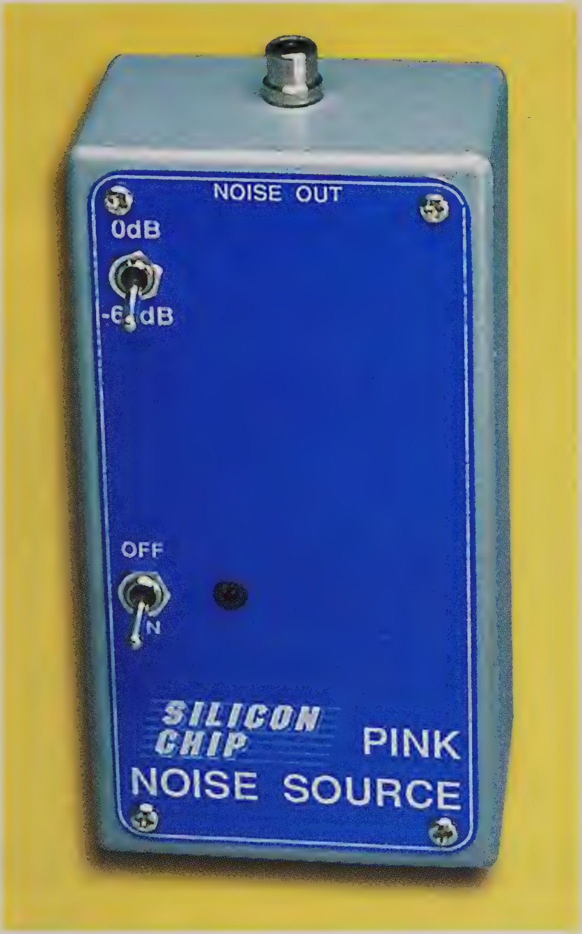


Fig.8: this is the actual size artwork for the front panel.

BUILD THIS

Pink Noise Source

For sound level meter calibration & signal balancing



You can use this Pink Noise Source as an aid to calibrating the Sound Level Meter described on page 82. It can also be used as a general purpose signal for setting the balance between loudspeakers in a multichannel (2, 4 or more channels) system and for PA adjustments.

By JOHN CLARKE

While noise is usually considered a nuisance, it can be useful in some cases. In audio applications it provides us with a signal which covers the entire audible spectrum. This means that there is every conceivable frequency from 20Hz up to 20kHz, all in the one signal.

Armed with this type of signal we can obtain frequency response measurements and a wideband sound level output for loudspeakers. Also it provides a standard sound for subjective listening tests. With an analyser and equaliser we can also adjust the frequency levels from a loudspeaker in a particular room so that it provides a flat response across the audible spectrum.

All of these measurements assume that the noise source has a flat frequency response or an equal energy per octave. This is called “pink” noise. The energy from 20Hz to 40Hz must be the same as that from 10kHz to 20kHz even though there is only a

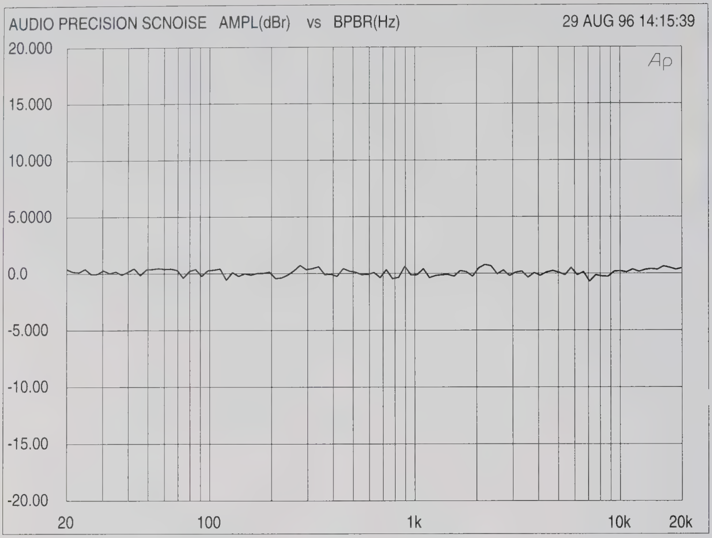


Fig.1: the spectrum (signal output versus frequency) of the Pink Noise Source. Since the noise source is random, a second response test would no doubt reveal a slightly different result, with perhaps dips in response where slight peaks are shown and vice versa.

20Hz difference in frequency for the lowest octave and a 10kHz range for the upper octave. Fig.1 shows the spectrum (ie, signal output versus frequency) of the Pink Noise Source featured in this article.

By contrast, the noise from electronic circuits is "white". It has a 3dB rise in output per octave of frequency since it has equal energy per constant bandwidth. So the octave band from 20Hz to 10.02kHz will have the same energy level as the octave between 10kHz and 20kHz.

Rose-coloured filter

To convert white noise to pink noise we need a filter which has a 3dB/octave or 10dB/decade rolloff. This is a little tricky since a normal single pole low pass filter will roll off at 6dB/octave (or 20dB per decade). A "pink" filter is achieved by rolling the signal off in four discrete steps, introducing further filtering as the frequency rises.

Main Features

- Pink noise signal output
- Battery operated
- 0dB and -60dB levels
- Power-on LED

Fig.2 shows the pink noise circuit. It uses a transistor noise source, two op amps for amplification and some passive filtering.

An NPN transistor, Q1, is connected for reverse breakdown between the emitter and base, with current limiting provided by the 180kΩ resistor from base to ground. This provides a good white noise source but it only produces a low signal level.

Op amp IC1a amplifies this noise by a factor of 101. IC1a is AC-coupled and biased to the 4.5V half supply rail to provide a symmetrical swing at its output, pin 1. The 0.27μF input capacitor and bias resistor roll off the response below 0.6Hz. Similarly, the 2.2kΩ resistor and 100μF capacitor in the feedback path at pin 2 roll off response below 0.7Hz. High frequency rolloff above 153kHz is provided by the 4.7pF capacitor across the 220kΩ resistor.

Following pin 1 of IC1a is a passive RC filter to roll off the frequency response at 3dB per octave. This filter is

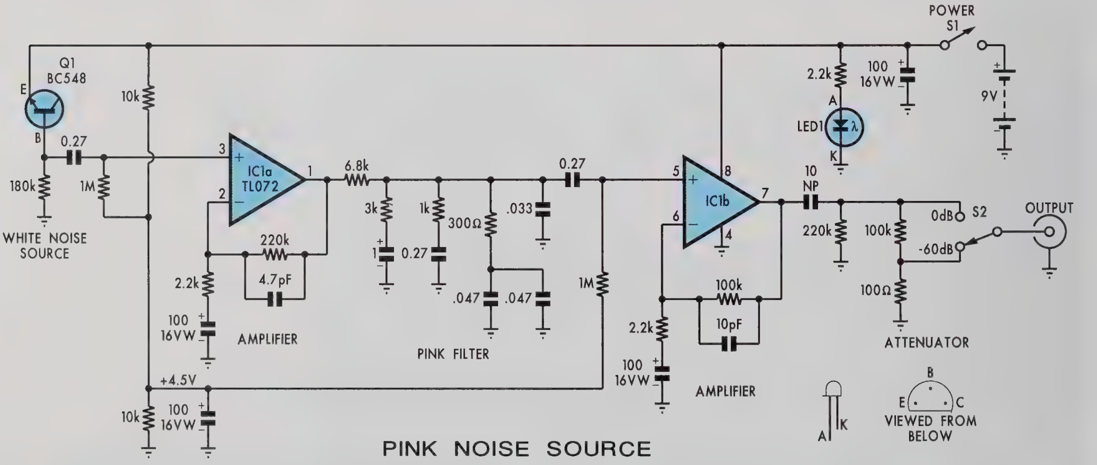

POWER
S1
Q1
BC548
E
B
10k
0.27
180k
1M
WHITE NOISE SOURCE
3
2
IC1a
TL072
1
2.2k
100 16VW
220k
4.7pF
AMPLIFIER
+4.5V
10k
100 16VW
6.8k
3k
1
1k
0.27
300Ω
.033
.047
.047
PINK FILTER
0.27
1M
5
6
8
IC1b
4
7
2.2k
100 16VW
100k
10pF
AMPLIFIER
2.2k
A
LED1
K
100 16VW
9V
10 NP
220k
100k
100Ω
0dB
S2
-60dB
OUTPUT
ATTENUATOR
A
K
B
E
C
VIEWED FROM BELOW
PINK NOISE SOURCE

Fig.2: the pink noise circuit uses a transistor noise source, two op amps for amplification and some passive filtering.

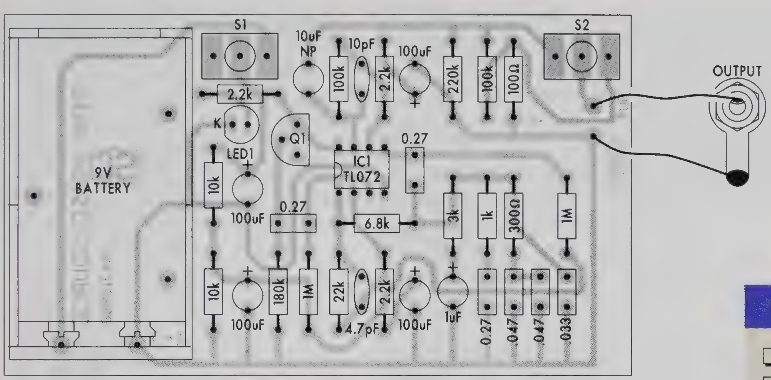


Fig.3 (left): the component layout and wiring details. Note that the two switches are mounted on PC stakes and be sure to mount all polarised components with the correct orientation.

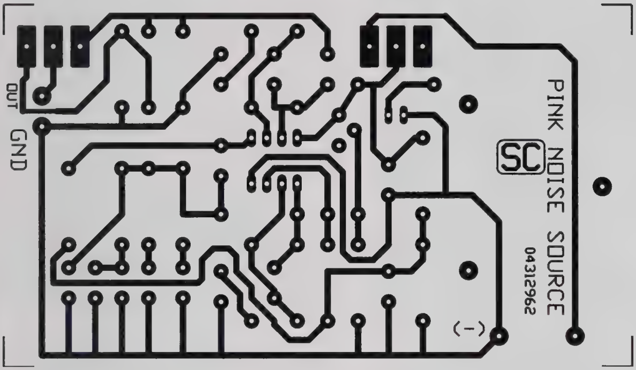


Fig.4: check your etched PC board against this full-size artwork before installing any of the parts.

Capacitor Codes

☐	Value	IEC	EIA
☐	0.27µF	270n	274
☐	.047µF	47n	473
☐	.033µF	33n	333
☐	10pF	10p	10
☐	4.7pF	4p7	4.7

accurate to ±0.25dB from 10Hz to 40kHz, assuming the use of close tolerance capacitors. The spectrum response shown in Fig.1 is that of the prototype using normal 10% tolerance capacitors.

Note that the signal levels shown in Fig.1 are the actual levels at the instant the measurement was taken. Since the noise source is random, a second response test would no doubt reveal a slightly different result, with perhaps dips in response where slight peaks are shown and vice versa.

The pink noise output is AC-coupled into op amp IC1b which has a gain of 46. This has a low and high frequency response rolloff similar to IC1a.

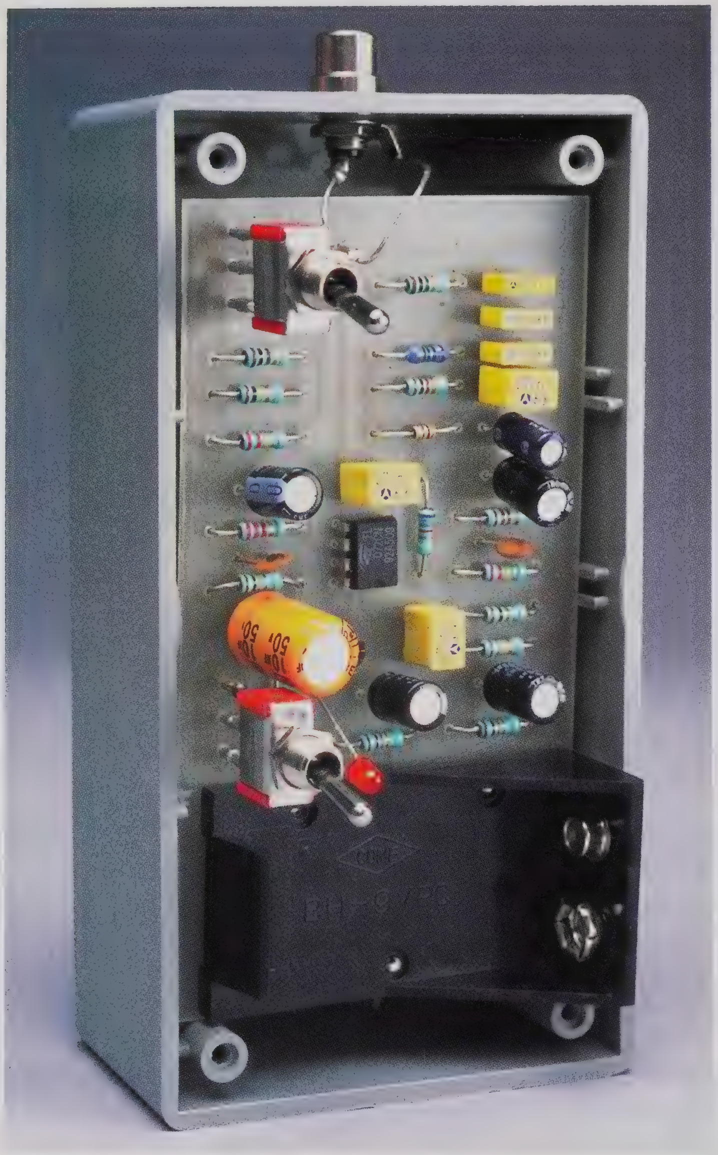
IC1b's output is AC-coupled to switch S2. Note that a non-polarised

Performance

Output levels	60mV RMS at 0dB; 60µV at -60dB
Maximum output load	1kΩ (for <1dB error in 60dB attenuator)
Frequency spectrum	<0.25dB 20Hz to 20kHz (see Fig.1)
Power supply	7.6V to 9V at 7mA

Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	2	1MΩ	brown black green brown	brown black black yellow brown
☐	2	220kΩ	red red yellow brown	red red black orange brown
☐	1	180kΩ	brown grey yellow brown	brown grey black orange brown
☐	2	100kΩ	brown black yellow brown	brown black black orange brown
☐	2	10kΩ	brown black orange brown	brown black black red brown
☐	1	6.8kΩ	blue grey red brown	blue grey black brown brown
☐	1	3kΩ	orange black red brown	orange black black brown brown
☐	3	2.2kΩ	red red red brown	red red black brown brown
☐	1	1kΩ	brown black red brown	brown black black brown brown
☐	1	300Ω	orange black brown brown	orange black black black brown
☐	1	100Ω	brown black brown brown	brown black black black brown



The construction is easy since all parts except for the RCA output socket are mounted on the PC board.

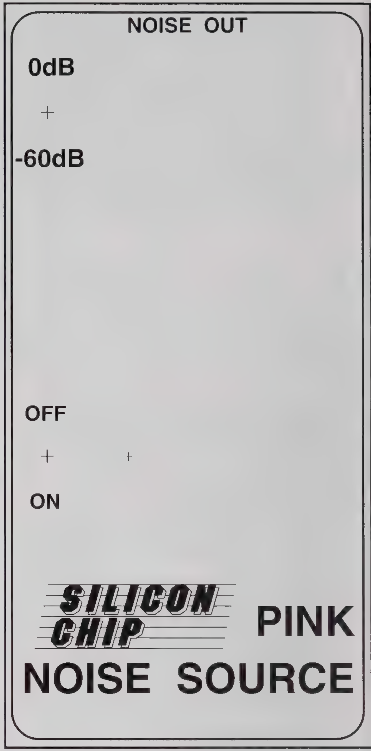


Fig.5: this is an actual size artwork for the front panel.

(NP) capacitor is specified. This is because the noise source is designed to connect to the Sound Level Meter which would reverse polarise a normal electrolytic type. Switch S2 selects the full output (0dB) or a divide by 1000 using the 100kΩ and 100Ω resistors for a -60dB output.

The 4.5V half supply is derived from a 10kΩ resistive divider which is decoupled using a 100µF capacitor. The power LED is driven via a 2.2kΩ resistor while the whole supply is decoupled using a 100µF capacitor.

Construction

The Pink Noise Source is housed in a plastic case measuring 130 x 67 x 41mm. The circuitry fits onto a PC board coded 04312962 and measuring 104 x 60mm. The wiring details are shown in Fig.3.

Begin construction by checking the PC board for defects. This done, install the resistors and install PC stakes at the switch positions. The PC stakes are required to allow the switches to be mounted above the PC board.

The capacitors can be mounted next, while ensuring correct orientation of the electrolytics. The 10µF NP capacitor can be mounted either way around. LED1 is mounted with its leads at full length, so that it can protrude through the front panel lid. Splay the leads slightly to give the LED some vertical adjustment, without one lead shorting to the other.

Next, insert transistor Q1 and IC1. Attach the battery holder using small self-tapping screws from the underside of the PC board. The toggle switches can be soldered in place on top of the PC stakes.

Attach the front panel label on the lid of the case and drill out the holes for the switches, LED bezel and cor-

Parts List

1 plastic case, 130 x 67 x 41mm
1 PC board, code 04312962, 104 x 60mm
1 self-adhesive label, 61 x 123mm
2 SPDT toggle switches (S1,S2)
1 panel mount RCA socket
1 9V battery holder
1 9V battery
1 3mm LED bezel
8 PC stakes
3 small self-tappers for the battery holder

Semiconductors
1 TL072 dual op amp (IC1)
1 BC548 PNP transistor (Q1)
1 3mm red LED (LED1)

Capacitors
4 100µF 16VW PC electrolytic
1 10µF NP PC electrolytic
1 1µF 16VW PC electrolytic
3 0.27µF MKT polyester
2 .047µF MKT polyester
1 .033µF MKT polyester
1 10pF ceramic
1 4.7pF ceramic

Resistors (0.25W 1%)
2 1MΩ
2 220kΩ
1 180kΩ
2 100kΩ
2 10kΩ
1 6.8kΩ
1 3kΩ
3 2.2kΩ
1 1kΩ
1 300Ω
1 100Ω

ner mounting locations. Also drill a hole in the end of the case for the RCA socket. Attach the socket and clip the PC board in place against the integral side pillars of the box. Wire up the RCA socket as shown in Fig.3.

Finally, insert the battery and attach the lid with the LED bezel in place. Take care to ensure that the LED protrudes through the bezel before tightening the case screws.

Testing

You can test the unit by connecting the output to an amplifier and speaker. Apply power and listen to the noise which should occur after several seconds. Alternatively, look at the signal on an oscilloscope. A multimeter should give an AC reading of around 60mV on the 0dB range and 0V on the -60dB position of S2. **SC**

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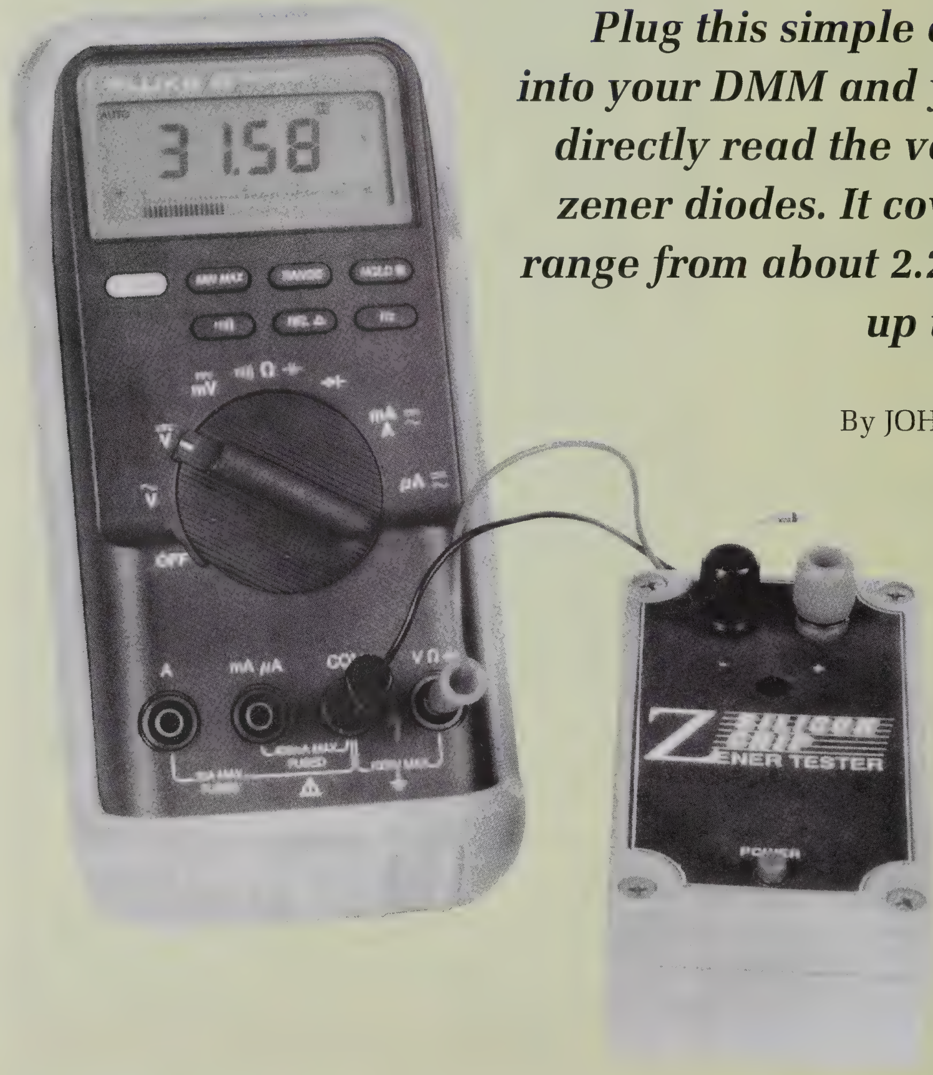
Check out those unknown components

A zener diode tester for your DMM

Plug this simple adaptor into your DMM and you can directly read the values of zener diodes. It covers the range from about 2.2V right up to 100V.

By JOHN CLARKE


31.58
SILICON CHIP
ZENER TESTER
POWER

HOW MANY ZENER DIODES do you have stashed away which cannot be used simply because their value is unknown? In many cases, the type number will be missing (rubbed off) or will be very difficult to read because the print is so small. And even if it can be read, the type number will not directly give you the value you anyway – instead, you have to look it up in a data book.

This Zener Tester is the answer to this problem. It plugs directly into your DMM, so that you can directly read the breakdown voltage of the zener being tested. The unit can measure all the common types from very low values of around 2.2V right up to 100V. It's best for 400mW and 1W power devices, although it will also provide a reasonably accurate measurement for 3W zeners.

Testing zener diodes

Testing zener diodes has always been difficult. This is because the current needed to test a low-voltage zener is vastly different to that required for a higher voltage type.

In the past, many zener testers tried to circumvent this problem by applying a constant 5mA and then reading off the value of breakdown voltage. Thus, for a 5V zener, the power dissipated would be 25mW and for a 30V zener, 150mW. While these values may appear OK, let's see why the constant current idea does not work in practice.

Fig.1 shows the typical zener characteristic. In the forward direction, the zener behaves as a diode and begins to conduct at about 0.7V. Conversely, in the reverse direction, there is very little current flow (as in a normal diode), until the "knee" is reached. At this point, the zener breaks down and the voltage remains essentially constant over a wide range of currents.

Note the maximum power position (the power rating of the zener) and the 10% maximum power location. These two power limits set the operating range of the zener.

If the current is taken below the 10% maximum power position, the zener voltage will drop markedly as it follows the knee in the curve. This means that if we read the zener voltage below the 10% position, the reading will be well under the correct zener voltage which can only be obtained at higher currents.

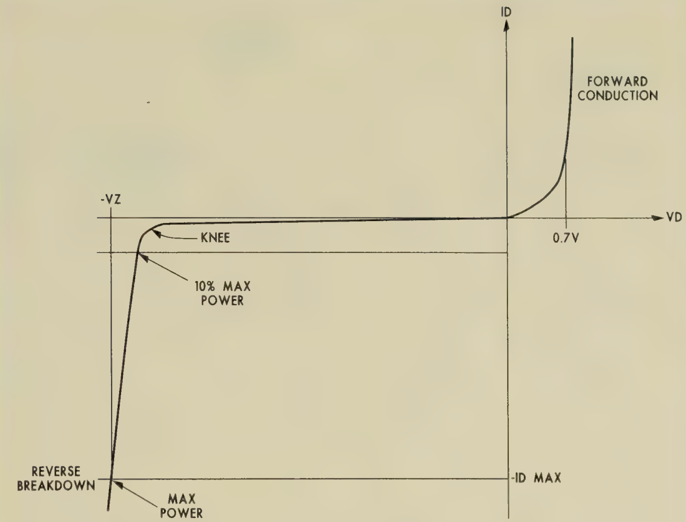


Fig.1: the typical zener characteristic. In the reverse direction, there is very little current flow until the "knee" is reached, at which point the zener breaks down and the voltage remains virtually constant over a wide range of currents.

Note: some zener diode types have a very sharp knee, which enables the diode to operate at very low currents while maintaining its rated breakdown voltage.

Features

- Tests 400mW and 1W zener diodes
- Test range from 2.2V to 100V
- Constant power testing at 200mW
- Connects to a multimeter for zener voltage reading
- Battery powered

Fig.2 shows the curves for both 1W and 400mW zener diodes for voltages from 3-100V. The lower two traces show the 40mW (10% of 400mW) and the 100mW (10% of 1W) power curves, while the upper two traces show the maximum power curves for 400mW and 1W.

To properly test 400mW and 1W diodes, we must have the zeners operate between the 100mW and 400mW curves. In this way, we will be above the 10% power point for both types and below their maximum limits.

The trace (dotted) for a zener tester using a constant 5mA current shows

Specifications

Zener diode test power	200mW
Test power linearity	within 10% of 200mW for zener diodes from 4V to 100V; less than 3.5% change for battery supply variation from 6-9V
Battery current drain	35mA @ 9V; 47mA @ 6V
Open circuit output voltage	112V nominal
Overall efficiency	63%
Converter efficiency	>90%

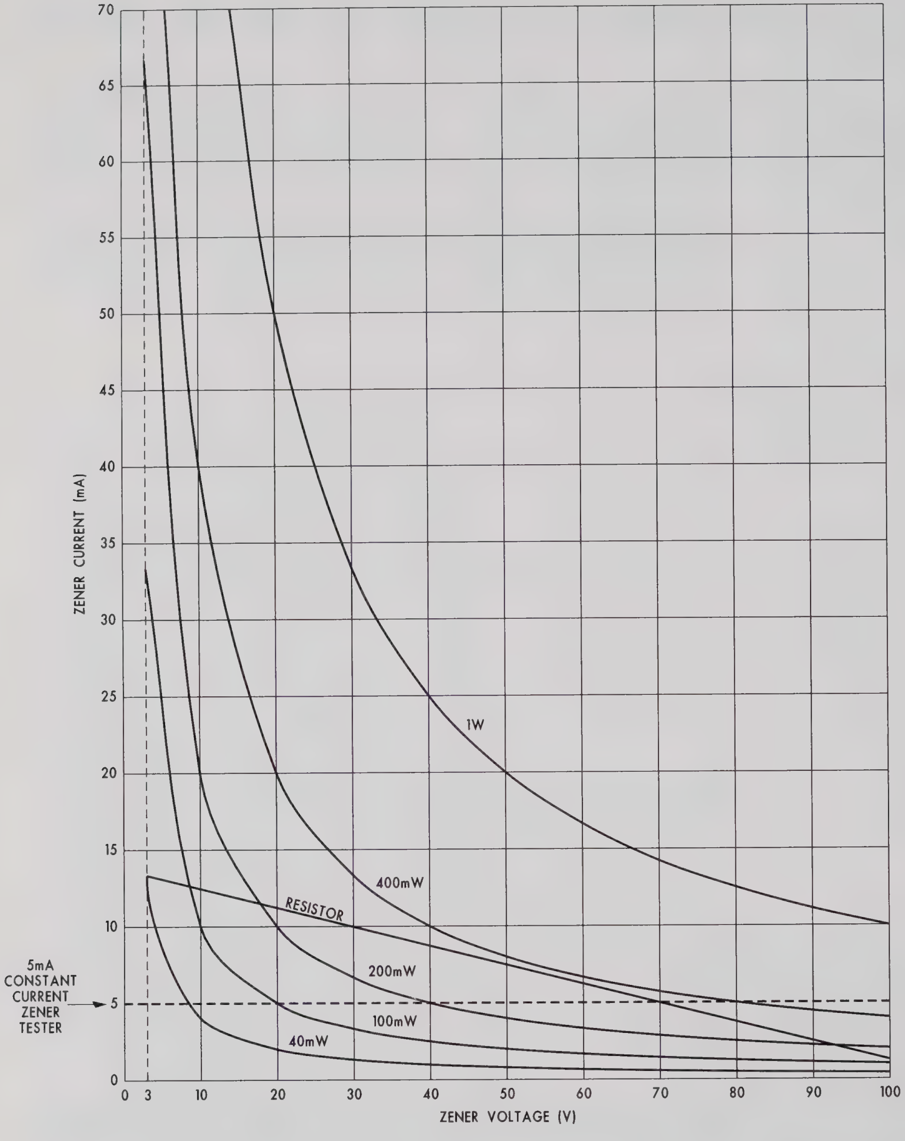


Fig.2: voltage vs. current curves for both 1W and 400mW zener diodes, for voltages from 3-100V. The lower two traces show the 40mW (10% of 400mW) and the 100mW (10% of 1W) power curves, while the upper two traces show the maximum power curves for 400mW and 1W.

that while zeners from 20-80V fit between these limits, the maximum dissipation is exceeded for 400mW diodes above 80V. At the other end, the 10% limit prevents 1W diodes from giving accurate readings below 20V (for 400mW diodes, the limit is extended to below 8V).

One way around this is to use a fixed resistor tester operating from a 110V supply. This will enable all 400mW and 1W zener diodes to be tested down to about 3V. Note, however, that this type of tester will go close to the 400mW limit at about 66V.

At the same time, the tester will also need to provide up to 1.42W of power to dissipate 40mW in a 3V zener. This represents an efficiency of just 3%. While efficiency may not appear to be a problem, it does present a strain on a small 9V battery when it is called upon to deliver 160mA.

The final trace shows the 200mW power curve and this fits neatly between the limits specified. The SILICON CHIP Zener Tester follows this curve closely. It always provides the same power to the zener diode, regardless of voltage. And, as a bonus, battery drain is much lower at 35mA.

Block diagram

The Zener Tester is based on a high voltage supply, produced by stepping

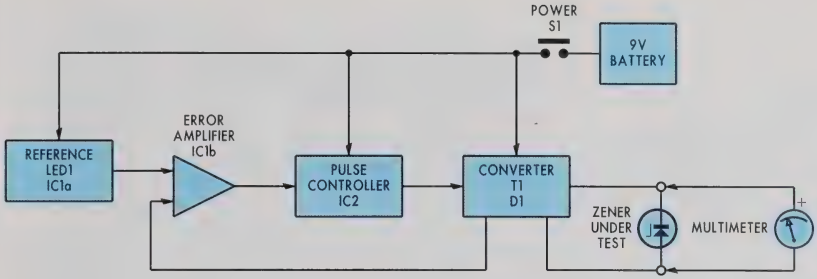

POWER
S1
9V
BATTERY
REFERENCE
LED1
IC1a
ERROR
AMPLIFIER
IC1b
PULSE
CONTROLLER
IC2
CONVERTER
T1
D1
ZENER
UNDER
TEST
MULTIMETER
+

Fig.3: block diagram of the Zener Tester. It uses a converter to step up the voltage from a 9V battery so that high-voltage zeners can be tested. The error amplifier and pulse controller ensure that the power delivered to the zener diode remains constant.

up from 9V using a converter – see Fig.3. This converter produces up to about 112V, so that high-voltage zeners can be tested.

The current supplied to the converter is monitored by error amplifier IC1b which in turn drives a pulse controller (IC2). This maintains a constant current to the converter from the 9V battery. Since the battery voltage is also constant, the power delivered to the converter and thus to the zener is also constant.

In practice, this means that the converter alters its current output depending on the zener voltage. At high zener voltages, the current is low and at low voltages, the current is high.

A LED reference is used to provide a fixed voltage for the error amplifier, so that current can be maintained. Note that this reference is also compensated for input voltage, so that as the battery voltage falls, the reference voltage rises and allows more current flow through the converter. This maintains the constant power to the converter, regardless of variations in the supply voltage.

A standard digital or analog multimeter is used to read the value of zener voltage.

How it works

The full circuit for the Zener Tester is shown in Fig.4. It consists of just a few low-cost components and a step-up transformer.

The step-up circuit uses the two windings of transformer T1 to produce up to 112V. Mosfet transistor (Q1) is used as a switch to charge the primary winding via the 9V supply. When Q1 is switched off, the charge is transferred to the secondary and delivered to a 0.1µF capacitor via diode D1.

The advantage of using a 2:1 step-up transformer is that the voltage developed across Q1 is only half that developed across the secondary winding. This means that a 60V Mosfet can be used rather than a 200V type.

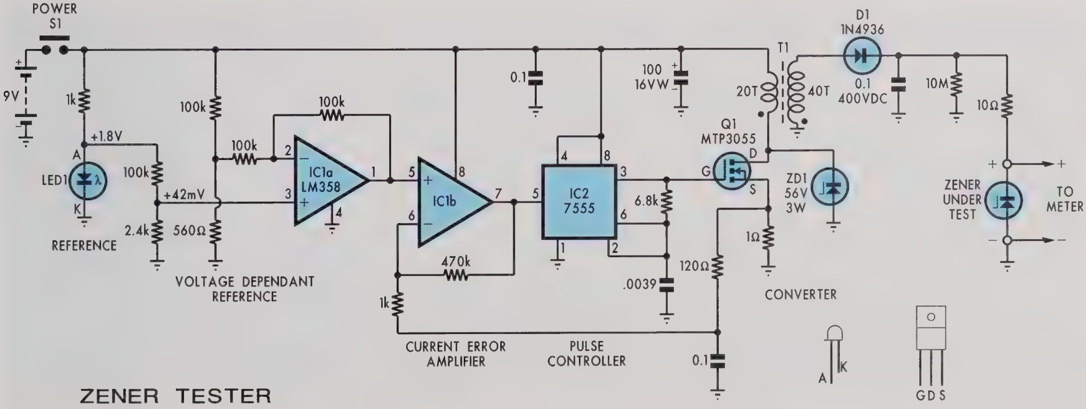
Q1 is driven by an oscillator formed by 7555 timer IC2. This operates by successively charging and discharging a .0039µF capacitor via a 6.8kΩ timing resistor connected to the output (pin 3).

When power is first applied, the .0039µF capacitor is discharged and the pin 3 output is high. The capacitor then charges to the threshold voltage at pin 6, at which point pin 3 goes low and the capacitor discharges to the lower threshold voltage at pin 2. Pin 3 then switches high again and so the process is repeated indefinitely while ever power is applied.

The current through Q1 is monitored by measuring the voltage across the 1Ω source resistor. This voltage is filtered using a 120Ω resistor and a 0.1µF capacitor and applied to error amplifier IC1b. Its output (pin 7) directly drives the threshold pin (pin 5) of IC5.

If the current is too high, IC1b pulls pin 5 of IC2 slightly lower, so that the pulse width duty cycle to Q1 is re-

Fig.4 (below): the circuit diagram of the Zener Tester. IC1b is the error amplifier and this controls the duty cycle of oscillator IC2. IC2 in turn drives Q1 which switches the primary of step-up transformer T1. The secondary output of T1 is then rectified via D1 and applied to the zener diode.


POWER
S1
9V
1k
+1.8V
LED1
A
K
λ
REFERENCE
100k
+42mV
2.4k
100k
560Ω
100k
VOLTAGE DEPENDANT
REFERENCE
100k
IC1a
LM358
2
3
1
4
8
5
6
7
IC1b
470k
1k
CURRENT ERROR
AMPLIFIER
0.1
IC2
7555
4
8
3
5
6
1
2
6.8k
.0039
PULSE
CONTROLLER
100
16VW
T1
20T
40T
Q1
MTP3055
G
D
S
ZD1
56V
3W
1Ω
120Ω
0.1
CONVERTER
D1
1N4936
0.1
400VDC
10M
10Ω
ZENER
UNDER
TEST
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+
−
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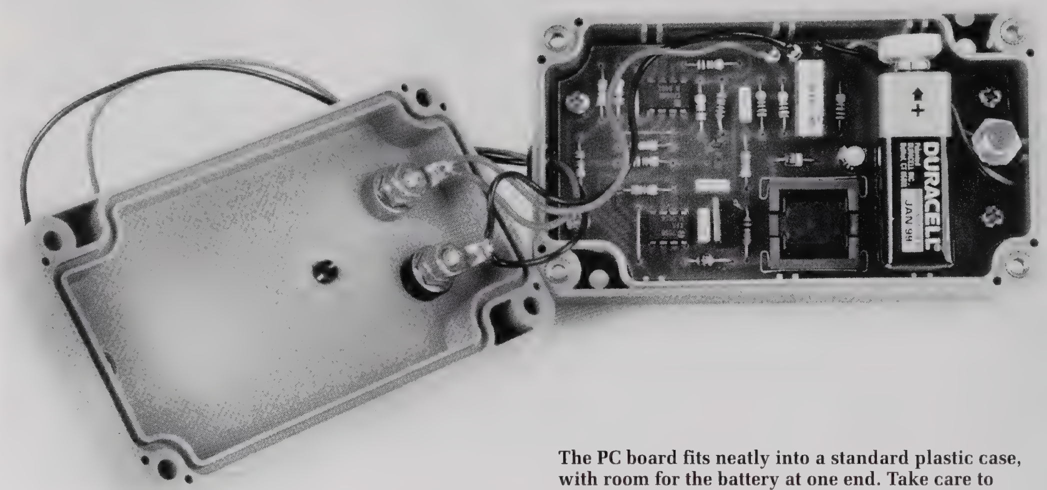
ZENER TESTER



The PC board fits neatly into a standard plastic case, with room for the battery at one end. Take care to ensure that the test terminals are correctly wired.

duced. This in turn reduces the current. Conversely, if the current is too low, IC1b pulls pin 5 of IC2 higher. This increases the duty cycle of the drive to Q1's gate and thus increases the current.

IC1b compares the average current value with a reference at its pin 5 (non-inverting) input. This reference is derived from the power supply and LED1 via IC1a.

In operation, pin 2 of IC1a monitors a voltage dependant reference derived from a voltage divider (100kΩ & 560Ω) across the supply rails. This reference is fed to pin 2 via a 100kΩ resistor, while a 100kΩ feedback resistor gives the amplifier a gain of -1 for this signal path.

Similarly, the 1.8V that appears across LED1 is divided using 100kΩ and 2.4kΩ resistors to give about 42mV at pin 3 of IC1a. IC1a then amplifies this signal by a factor of 2 (1 + 100kΩ/100kΩ) to give 84mV.

To understand how this all works in practice, let's assume that the power supply is at 9V. In this case, the voltage across the 560Ω resistor will be 50mV and so the output (pin 1) of IC1a will be at 84 - 50 = 34mV. However, if the power supply falls to 7.5V (for example), then the voltage across the 560Ω resistor will be 42mV. The pin 1 output of IC1a will now be at 84 - 42mV = 42mV.

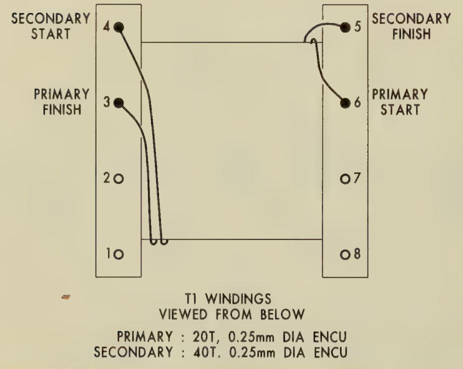


Fig.5: this diagram shows the winding details for the step-up transformer (T1) – see text. Note that both windings are wound in the same direction.

Thus, as the supply voltage goes down, the reference voltage applied to pin 5 of IC1b goes up. This ensures that greater current is supplied at lower voltages, to maintain the constant power. As the accompanying specifications panel shows, this scheme works well, with the power varying by only 3.5% for battery voltage ranging from 6-9V.

Power supply

Power for the circuit is derived from the 9V battery via switch S1. Note that the battery condition is indicated by the brightness of the LED. If LED1 is dim, then it is time to change the battery. The fact that the circuit will work down to below 6V means that battery life is quite good.

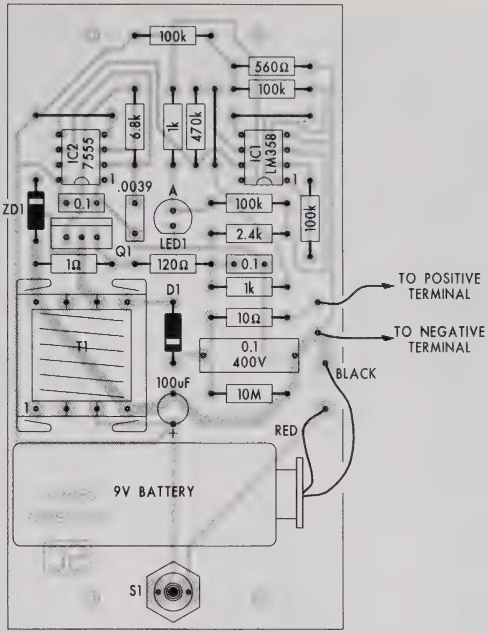
Construction

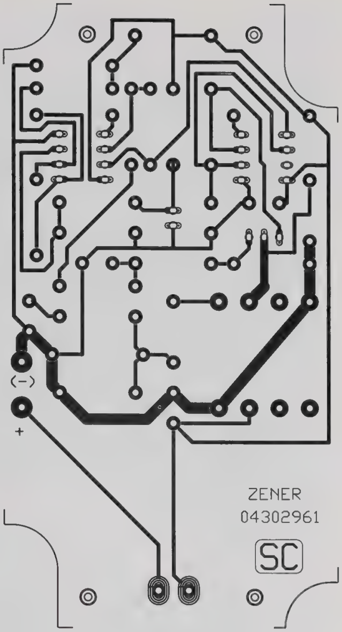
Construction of the SILICON CHIP Zener Tester is straightforward, with most of the parts mounted on a PC board coded 04302961 (56 x 104mm).

Begin construction by checking the PC board for shorted tracks or small breaks. In addition, the corners of the PC board will need filing out so that it will fit inside the case. The actual shape is shown on the copper side of the PC board.

This done, install PC stakes at the

Fig.6 (right): make sure that transformer T1 is correctly oriented when installing the parts on the PC board (ie, pin 1 to bottom left). Fig.7 (far right) shows the full-size PC pattern.





external wiring points – see Fig.6. These are located at the positive (+) and negative (-) battery wiring points, at the positive and negative terminal connection positions, and at the switch (S1) and LED1 positions. Once these are in, install the two wire links (next to IC1 and next to IC2).

Next, install the resistors, followed by the diodes and ICs. Table 1 lists the resistor colour codes but it is also a good idea to check them using a digital multimeter. Make sure that the diodes and ICs are correctly oriented.

The capacitors can now be installed, taking care to ensure that the 100µF electrolytic is oriented correctly. This done, install Mosfet Q1 on the board (metal tab towards IC2). LED1 is mounted on the end of its leads, so that it will later protrude through the front panel. Similarly, switch S1 is soldered on the top of its corresponding PC stakes.

Transformer winding

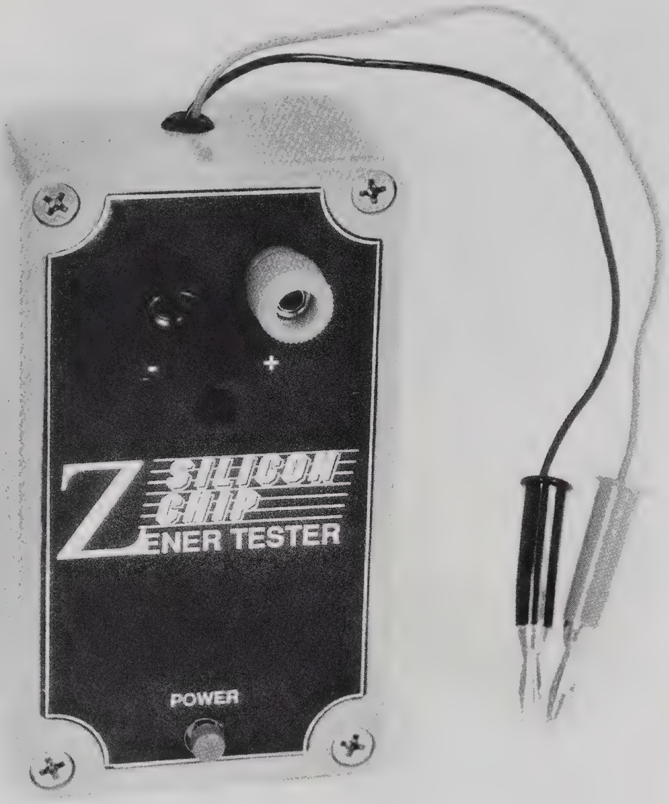
Transformer T1 is wound using 0.25mm enamelled copper wire – see Fig.5. The primary is wound first, as follows: (1) remove the insulation from one end of the wire using a hot soldering iron tip and terminate this end on pin 6; (2) wind on 20 turns side-by-side in the direction shown and terminate the free end on pin 3; (4) wrap a layer of insulating tape around this winding.

The secondary is wound on in similar fashion, starting at pin 5 and winding in the direction shown. Note that the 40 turns are wound on in two layers (20 turns in each), with a layer of insulating tape between them. Terminate the free end of the winding on pin 4.

The transformer is now assembled by sliding the cores into each side of the former and then securing them

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	10MΩ	brown black blue brown	brown black black green brown
☐	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
☐	4	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	6.8kΩ	blue grey red brown	blue grey black brown brown
☐	1	2.4kΩ	red yellow red brown	red yellow black brown brown
☐	2	1kΩ	brown black red brown	brown black black brown brown
☐	1	560Ω	green blue brown brown	green blue black black brown
☐	1	120Ω	brown red brown brown	brown red black black brown
☐	1	10Ω	brown black black brown	brown black black gold brown
☐	1	1Ω	brown black gold gold	brown black black silver brown



The test leads are fitted with banana plugs (red for positive, black for negative), so that they can be plugged into standard multimeter terminals. The zener breakdown voltage is the read directly off the multimeter display.

with the clips. This done, insert the transformer into the PC board, making sure that it is oriented correctly, and solder the pins.

Final assembly

A plastic case measuring 64 x 114 x 42mm is used to house the assembled PC board. This is fitted with a self-adhesive label measuring 55 x 103mm.

Begin the final assembly by affixing the label to the front panel (lid), then drill out mounting holes for the LED bezel, switch S1 and the two banana plug terminals. You will also need to drill a hole in one end of the base to accept a small grommet. This done, mount the two test terminals (red for positive, black for negative) and fit the grommet and LED bezel in place.

Next, fit the board inside the case (it sits on four integral mounting pillars) and secure it using four small self-tapping screws. The lid can now be test fitted to check that the switch and LED line up correctly with the front panel. Adjust them for height as necessary, then solder the battery clip leads to their respective PC stakes.

Finally, run short lengths of hookup wire from the PC board to the test terminals. Additional leads are then attached to the test terminals and brought out via the grommet fitted to one end of the case. Terminate these leads using banana plugs (red for positive, black for negative). This lets you plug the leads directly into a standard DMM or analog multimeter.

Testing

You are now ready to test the unit.

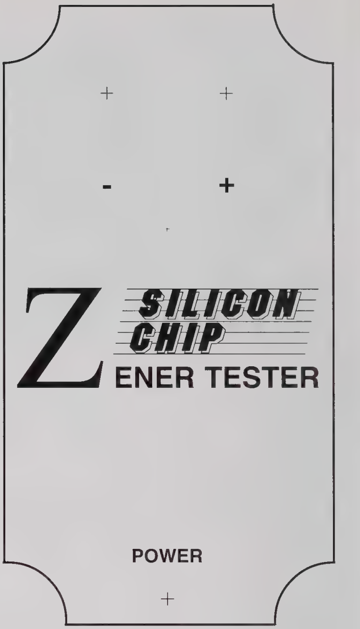


Fig.8: this full-size artwork can be used as a drilling template for the front panel.

Apply power and check that the LED lights. If is doesn't, check that the LED is oriented correctly. Now measure the voltages on IC1 using a multimeter. There should be about 9V DC across pins 4 & 8 and a similar voltage between pins 1 & 8 of IC2.

If these voltage checks are correct, plug the output leads into your multimeter and press the Power button. Check that the meter reads 112V. If it doesn't, switch off immediately and check for wiring errors.

If everything is OK so far, connect a 1kΩ resistor across the test terminals and check the voltage again (press the Power button). This time, you should get a reading of about 14V across the resistor, which means that the resistor is dissipating about 200mW. If this reading is quite different, check that the voltage across LED1 is 1.7-1.8V and that about 42mV at present on pin 3 of IC1.

Assuming a fresh battery, you should also get about 50mV across the 560Ω resistor. If the latter two reading are incorrect, check the associated voltage divider resistors.

If all is working correctly, you are now ready to measure zener diodes.

Parts List

- 1 PC board, code 04302961, 104 x 56mm
- 1 plastic case, 64 x 114 x 42mm
- 1 front panel label, 55 x 103mm
- 1 pushbutton momentary contact switch (S1)
- 1 9V battery and battery clip
- 1 red banana socket
- 1 black banana socket
- 1 red banana plug
- 1 black banana plug
- 1 EFD20 transformer assembly (Philips 2 x 4312 020 4108 1 cores, 1 x 4322 021 3522 1 former, 2 x 4322 021 3515 1 clips) (T1)
- 1 2-metre length of 0.25mm enamelled copper wire
- 1 100mm length of red hook-up wire
- 1 100mm length of black hook-up wire
- 1 30mm length of 0.8mm tinned copper wire
- 8 PC stakes
- 4 3mm screws
- 1 small grommet
- 1 3mm LED bezel

Semiconductors

- 1 LM358 dual op amp (IC1)
- 1 7555, TLC555, LMC555CN CMOS timer (IC2)
- 1 MTP3055E or A version N-channel Mosfet (Q1)
- 1 3mm red LED (LED1)
- 1 1N4936 fast recovery diode (D1)
- 1 56V 3W zener diode (ZD1)

Capacitors

- 1 100µF 16VW PC electrolytic
- 2 0.1µF MKT polyester
- 1 0.1µF 400VDC polyester
- 1 .0039µF MKT polyester

Resistors (0.25W, 1%)

- 1 10MΩ
- 1 470kΩ
- 4 100kΩ
- 1 6.8kΩ
- 1 2.4kΩ
- 2 1kΩ
- 1 560Ω
- 1 120Ω
- 1 10Ω
- 1 1Ω

There's just one important thing to watch out for here – be sure to connect the zener diode to the test terminals with the correct polarity; ie, cathode (banded end) to positive, anode to negative. **SC**

Computer Test Gear From Microgram

LAN Cable Tester – Cat. 11519.
Terminator
LAN CABLE TESTER

LAN CABLE TESTER: If you install LAN cabling as a profession or if you are an administrator caring for a small LAN, you need a LAN cable tester. There are lots of units available but this one from Microgram Computers is a bit smarter than the basic units.

The LAN Cable Tester can check both shielded and unshielded twisted pair Cat.3 and Cat.5 cables for continuity, open circuits, short circuits and cross wiring. The results are displayed on a 2-line LCD screen which indicates both the cable type detected and the pin connections. Any fault conditions detected are displayed in plain English. For example, if at least one pair is not connected, the display will read "NO CONNECT". A shorted cable will read "SHORT".

There are three different test modes: (1) Local Test for testing patch cables (both ends plugged into the main unit); (2) Remote Test, whereby the cable is connected between two identical main units; and (3) Terminator Loopback, in which the cable is connected between the main unit and a remote terminator ID block. Individual cables may also be identified by using multiple terminators, each with a different ID number (16 different fractory preset IDs are available).

Finally, it's also possible for the user to define a custom cable pin-out and store this in memory – a very handy feature for testing non-standard cables.

PCI-BUS DIAGNOSTIC CARD: you've just turned your computer on and it doesn't work. Is it the motherboard, the processor, the memory or what?

PCI-Bus Diagnostic Card – Cat. 3422.

This PCI Bus POST-Code Diagnostic Card will help identify the problem. Just plug it into a vacant PCI slot, turn on the computer and the 2-digit LED display shows a hexadecimal Power-On Self Test (POST) error code. By checking this error code against the appropriate BIOS listing in the manual, the type of fault can be identified (error codes are given for AMI, Phoenix and Award BIOS).

You can find out more from Microgram Computers, Unit 1, 14 Bon Mace Close, Berkeley Vale, NSW 2261. Phone (02) 4389 8444; email info@mgram.com.au or go to www.mgram.com.au.

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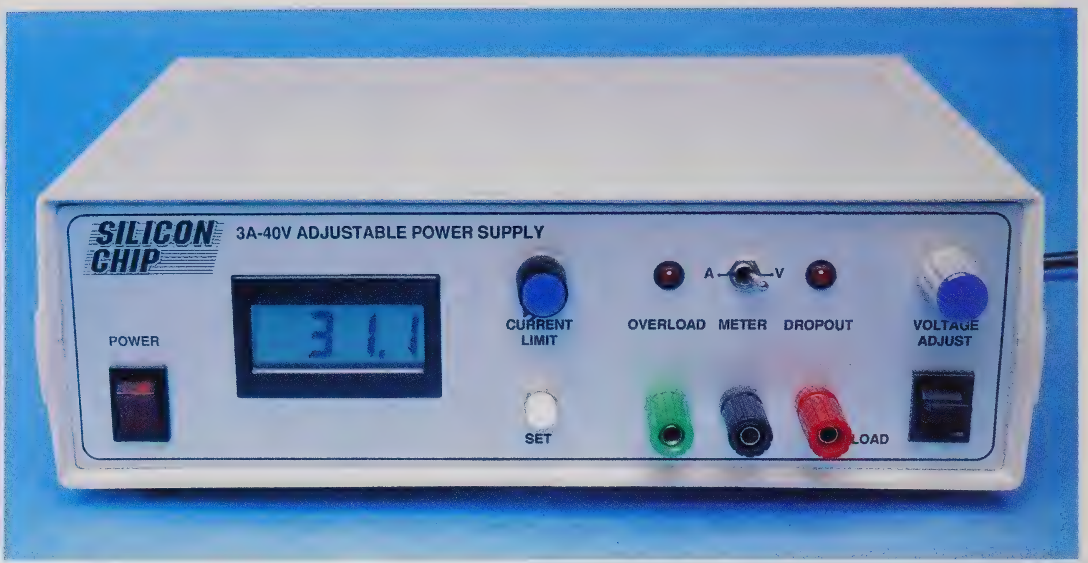


40V 3A variable power supply; Pt.1

This 1.23-40V adjustable power supply is designed for heavy-duty work. It uses a high-efficiency switching regulator circuit & features preset current limiting, full overload protection & an LCD panel meter for precise voltage & current readouts.

By JOHN CLARKE

BY FAR THE BIGGEST advantage that this elegant new power supply has over other designs is its high-efficiency switching regulator circuitry. In this type of circuit, the regulator is either fully on or fully off at any given instant and so it dissipates very little power, even when delivering high current at low output voltage.

In practical terms, this means that the regulator generates very little heat and so we don't need to use large and expensive heatsinks. And that in turn means that we can greatly simplify the construction and pack the required circuitry into a much smaller case than would otherwise be required for a conventional design employing a linear regulator.

In fact, by employing switchmode operation, the regulator in this circuit generates less than 10W under worst case conditions. By contrast, a linear regulator in an equivalent 40V supply would need to dissipate around 120W when delivering 1.23V at 3A! This is an enormous amount of heat to extract and would require a large finned heatsink to keep the regulator temperature within specification.

This is one power supply that can continuously supply a high output current without suffering from thermal overload problems. By contrast, a linear regulator has inherently high dissipation, especially at very low output voltages (due to the high voltage across the regulator), and this severely limits its output current capability.

Another very commendable feature is the low level of ripple and hash in the output. Achieving this is not always easy in a switchmode design but we've done it using a combination of extra filtering and careful circuit layout. As shown in the specifications panel, the output noise and ripple is just 5mV p-p at 24V, reducing to a

Main Features

- Output voltage continuously adjustable from 1.23V to 40V
- Greater than 3A output current capability from 1.23-28V
- Digital readout of voltage, current or current limit setting
- 10-turn pot for precise voltage adjustment
- Adjustable current limit setting
- Current overload indication
- Regulation dropout indication
- Output fully floating with respect to earth
- Load switch
- Low output ripple
- Short circuit & thermal overload protection
- Minimal heatsinking

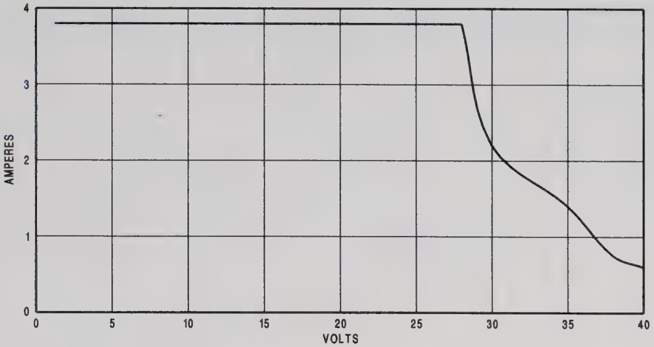


Fig.1: the voltage vs. current characteristics of the supply. It is capable of supplying a hefty 3.8A over the range from 1.23V to 28V. Beyond that, the available output current decreases due to the transformer regulation.

minuscule 1mV p-p at 3V.

These are excellent figures for a switching design and are comparable to those achieved by linear circuits. The switching hash is also very low. It is far less than in previous designs and, in fact, is below the ripple level.

Digital readout

Do you need to precisely monitor the output voltage or current, or accurately set the current limit? Well, with this power supply you can because it uses an LCD panel meter to give a digital readout of voltage or current. A single toggle switch selects the measurement mode.

A 10-turn pot makes it easy to set the output voltage to the exact value required, while the current limit is set by first pressing the Set button and then adjusting the Current Limit pot until the LCD shows the required value. In addition, there are two LEDs on the front panel and these provide current overload and regulation dropout indication.

There's one other control on the front panel that we haven't yet mentioned – the Load switch. This simply connects or disconnects the load (ie, the device being powered) from the supply rail and eliminates the need to switch the supply off when making connections to the output terminals. It also allows the output voltage and current limit values to be set before power is applied to the load.

Output capabilities

Fig.1 plots the performance of the supply. As shown, it is capable of supplying a hefty 3.8A over the range from 1.23V to 28V. Beyond that, the available output current decreases due to the transformer regulation. However, there is still 2.2A available at 30V, 1.4A at 35V and 600mA at 40V.

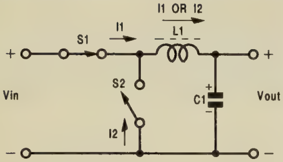


Fig.2: how a switching regulator operates. When S1 is closed & S2 is open, current flows to the load via L1 which stores energy. When S1 subsequently opens & S2 closes, the energy stored in the inductor maintains the load current until S1 closes again.

The load regulation is excellent at

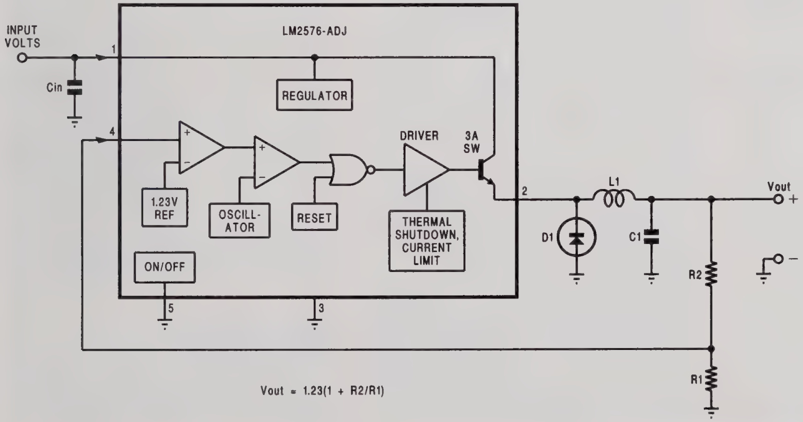


Fig.3: a basic switchmode voltage regulator based on the LM2576 IC. In this circuit, an internal 3A switching transistor takes the place of S1 in Fig.2, while diode D1 takes the place of S2. The output voltage is set by the ratio of R2 & R1, which feed a sample of the output voltage back to an internal comparator.

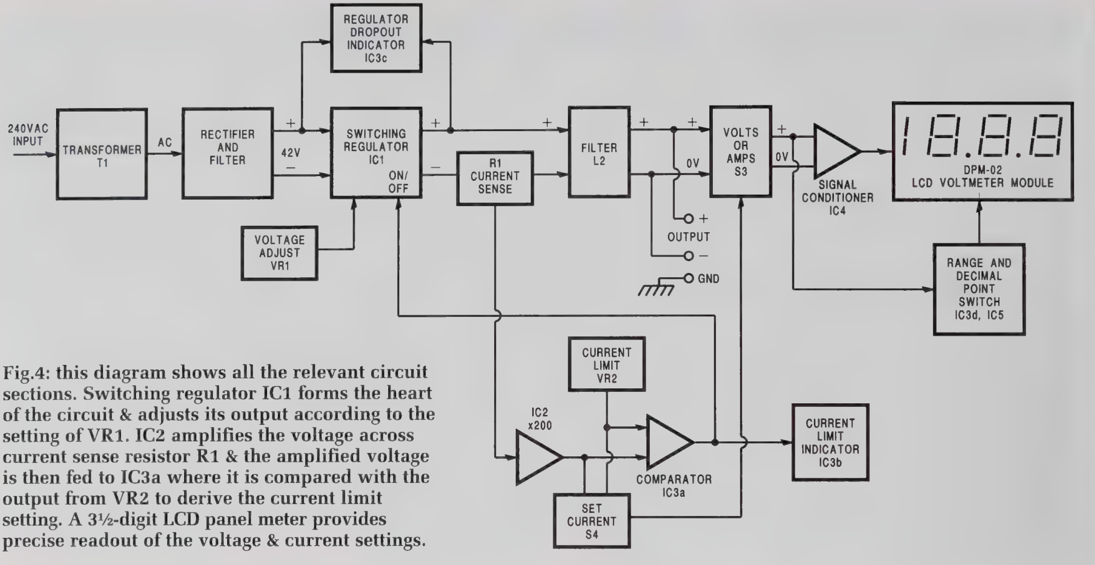


Fig.4: this diagram shows all the relevant circuit sections. Switching regulator IC1 forms the heart of the circuit & adjusts its output according to the setting of VR1. IC2 amplifies the voltage across current sense resistor R1 & the amplified voltage is then fed to IC3a where it is compared with the output from VR2 to derive the current limit setting. A 3½-digit LCD panel meter provides precise readout of the voltage & current settings.

the higher voltages but is not as good at lower voltages. This is because of higher losses in the circuit due to the higher pulse currents involved at low voltage settings. The line regulation is less than 0.1% for a 10% change in mains voltage – see specifications panel.

Basic principle

The circuit is based on the National Semiconductor LM2576HVT high voltage adjustable switchmode voltage regulator. Fig.2 shows how a switching regulator operates.

In operation, S1 and S2 operate at high speed and are alternately closed and opened. These two switches control the current flowing in inductor L1. When S1 is closed and S2 is open, the current flows to the load via inductor L1 which stores up energy. When S1 subsequently opens and S2 closes, the energy stored in the inductor maintains the load current until S1 closes again.

The output voltage is set by adjusting the switch duty cycle and is equal to the input voltage multiplied by the ratio of S1's on time to its off time. Capacitor C1 is used to filter the resulting output voltage before it is applied to the load.

Fig.3 shows a complete voltage regulator based on the LM2576 IC. It is a 5-pin device which requires just five extra components to produce a basic working circuit. Its mode of operation is the same as that described in Fig.2 except that here a 3A switching transistor is used for S1, while an external diode (D1) is used for S2.

What happens in this case is that when the transistor is on, the current flows to the load via inductor L1 as before and D1 is reverse biased. When the transistor subsequently turns off, the input to the inductor swings negative (ie, below ground). D1 is now forward biased and so the current now flows via L1, the load and back through D1.

The output voltage is set by the ratio of R2 and R1, which form a voltage divider across the output (V_{out}). The sampled voltage from the divider is fed to pin 4 of the switcher IC and thence to an internal comparator where it is compared with a 1.23V reference. This sets V_{out} so that the voltage produced by the divider is the same as the reference voltage (ie, 1.23V).

Apart from the comparator and the switching transistor, the regulator IC also contains an oscillator, a reset circuit, an on/off circuit and a driver stage with thermal shutdown & current limiting circuitry. The incoming supply rail is applied to pin 1 of the IC and connects to the collector of the 3A switching transistor. It also supplies an internal regulator stage which then supplies power to the rest of the regulator circuit.

Basically, the LM2576 uses pulse width modulation (PWM) control to set the output voltage. If the output voltage rises above the preset level, the duty cycle from the driver stage decreases and throttles back the switching transistor to bring the output voltage back to the correct level. Conversely, if the output voltage falls, the duty cycle is increased and the switching transistor conducts for longer periods.

The internal oscillator operates at 52kHz ±10% and this sets the switching frequency. This frequency is well beyond the limit of audibility although, in practice, a faint ticking noise will occasionally be audible from the unit due to magnetostrictive effects in the cores of the external inductors.

One very useful feature of the LM2576 that we haven't yet mentioned is the On/Off control input at pin 5. As its name implies, this allows the regulator to be switched on or off using an external voltage signal. This feature is put to good use in this circuit to provide the adjustable current limiting feature, as we shall see later on.

Block diagram

Although the LM2576-ADJ forms the heart of the circuit, quite a few other parts are required to produce a

Specifications

Minimum no load output voltage	1.23V ±13mV
Maximum no load output voltage	40V
Output current	see graph
Current limit range	10mA to 4A
Current limit resolution	10mA
Line regulation	<0.1% for a 10% change in mains voltage
Voltmeter resolution	10mV from 1.23V to 16.5V (approx); 100mV from 16.5V to 40V
Current meter resolution	10mA
Meter accuracy	1% plus 2 digits
Load regulation	
no load to 3A @ 24V	1.5%
no load to 3A @ 12V	2%
no load to 3A @ 6V	2.8%
no load to 3A @ 3V	4.2%
Output ripple and noise	
3A @ 24V	5mV p-p
3A @ 12V	2mV p-p
3A @ 6V	1mV p-p
3A @ 3V	1mV p-p

practical working variable supply. Fig.4 shows the full block diagram of the unit.

Power for the circuit comes from the 240VAC mains. This feeds power transformer T1 and its output is rectified and filtered to provide a 42V DC supply which is then fed to the input of the switching regulator (IC1). VR1 sets the output voltage from the regulator and essentially forms one half of the voltage divider shown in Fig.3.

IC3c monitors the input and output voltages from the regulator and lights a LED when the difference between them is less than 3.3V. This indicates that the circuit is no longer regulating correctly. Following the regulator, the current in the negative rail flows through the sensing resistor R1. The voltage across this resistor is then amplified by IC2 and applied to comparator stage IC3a.

R1 has a value of just .005Ω, while IC2 operates with a gain of 200. This means that IC2's output voltage is numerically equivalent to the current (in amps) flowing through R1 (ie, IC2's output increases by 1V per amp). So, in addition to driving IC3a, IC2 is also used to drive the LCD digital voltmeter (via S4, S3 & IC4) to obtain current readings.

IC3a and potentiometer VR2 provide the current limiting feature. In operation, IC3a compares the voltage from IC2 with the voltage set by VR2. This voltage can be anywhere in the range from 0-4V, corresponding to current set limits of 0-4A. The circuit works as follows.

If IC2's output rises above the voltage set by VR2 (ie, the current through R1 rises above the set limit), IC3a's output goes high and turns off the switching regulator via the On/Off control. The current through R1 now falls until IC2's output falls below the voltage from VR2, at which point IC3a's output goes low and switches the regulator (IC1) back on again. The current now rises until the regulator is switched off again and so the cycle is repeated indefinitely.

By this means, IC3a switches the regulator on and off at a rapid rate to limit the current to the value set by VR2.

IC3a also drives comparator stage IC3b and this lights an indicator LED when ever current limiting takes place. Switch S4 selects between the outputs of IC2 and VR2, so that either the load current or the current limit setting is displayed on the LCD panel meter.

This makes it easy to set the current limit. All you have to do is press S4 and rotate VR2 (the Current Limit control) until the required value appears on the digital readout.

Immediately following R1 is a filter stage which is based mainly on inductor L2. This filter removes most of the ripple and high frequency noise from the positive and negative supply rails. The two supply rails are then applied to the load via S2.

Finally, the 3½-digit LCD panel meter is used to display either the output voltage, the output current or the current limit setting, depending on the positions of switches S3 and S4. The selected signal voltage is applied to the panel meter via signal conditioning amplifier IC4, which provides the required level shifting and attenuation.

For voltages up to about 18V, the display resolution is 10mV. It is then switched to a higher range with 100mV resolution to prevent over-range for output voltages above 20V. This task is performed using IC3d and IC5.

Circuit details

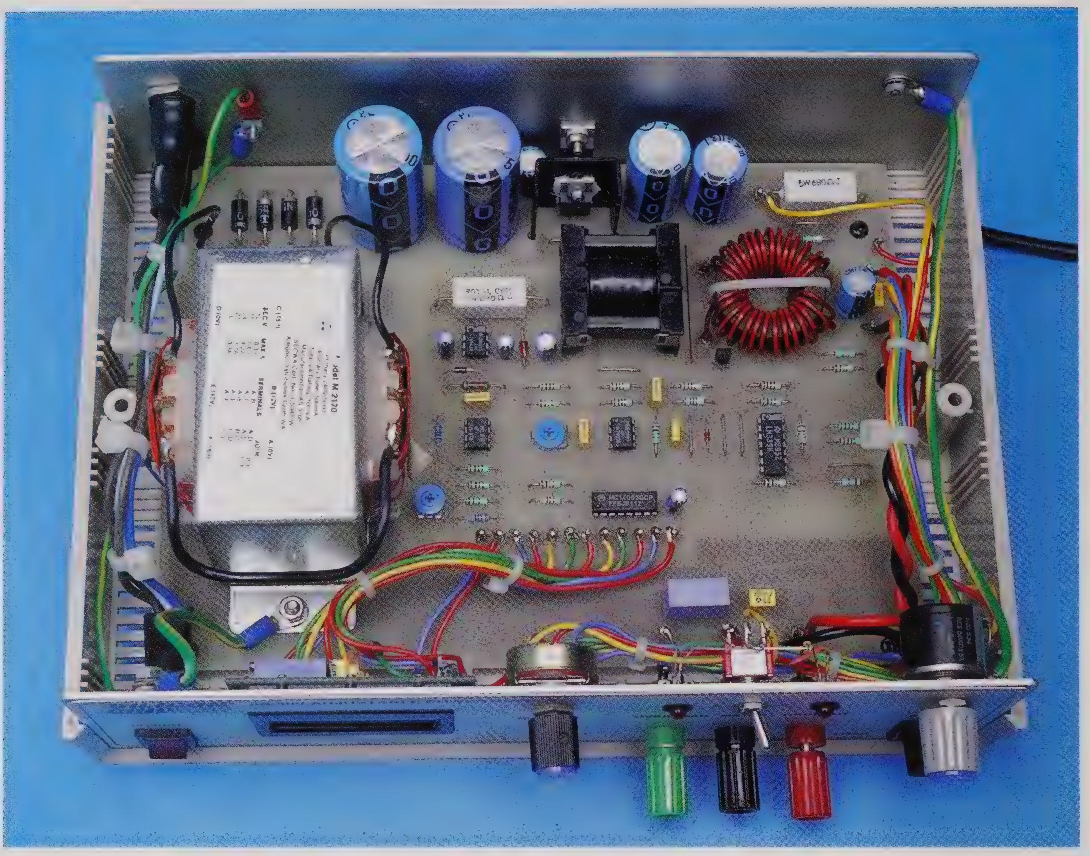
Refer now to Fig.5 for the full circuit details. It contains all the elements shown in the block diagram of Fig.4. We'll go through each of the major sections in turn.

Transformer T1 is supplied with mains power via fuse F1 and power switch S1. Its 30VAC secondary is full-wave rectified using diodes D1-D4 and filtered using two parallel 4700μF 50VW electrolytic capacitors. The resulting 42V DC supply is applied to the switching regulator (IC1).

Note the 100μF capacitor connected between pins 1 & 3 of IC1. This capacitor is necessary to prevent circuit instability and is mounted as close to the IC as possible.

D5, L1, the two parallel 1000μF capacitors and VR1 form the basic switchmode power supply block (see Fig.3). D5 is a Schottky diode which is rated at 10A and 60V. It has been specified in preference to a conventional fast recovery diode because of its low forward voltage drop. As a result, there is very little heat dissipation within the diode and this leads to increased efficiency.

The output from IC1 feeds directly into L1, a 300μH inductor. This inductor is wound on a Philips ETD29 ferrite core assembly with a 1mm airgap to prevent core saturation, as can occur when DC currents flow in



The power supply is easy to build since most of the parts are mounted on a single PC board & the LCD panel meter is supplied ready made. No large heatsinks are required in the design because the switching regulator (IC1) dissipates very little power, even at low-voltage high-current settings.

ungapped core windings.

VR1 and its associated 1.5kΩ resistor provide voltage feedback to pin 4 of IC1, to set the output level. When VR1's resistance is at 0Ω, the output from the regulator (pin 2) is equal to 1.23V. This output voltage increases as the resistance of the pot increases. The 680Ω 5W resistor connected across the regulator output discharges the two 1000µF capacitors to the required level when a lower output voltage is selected.

Filter circuit

Inductor L2 and its associated 100µF and 0.1µF capacitors make up the filter circuit shown in the block diagram (Fig.4). This LC network effectively attenuates the switching frequency ripple by a factor of 10.

In practice, L2 consists of two separate windings (L2a, L2b) on the same toroidal core. These two windings are phased so that the flux developed by L2a is cancelled by the flux developed by L2b. This type of winding arrangement provides what is known as DC compensation and is done to prevent core saturation.

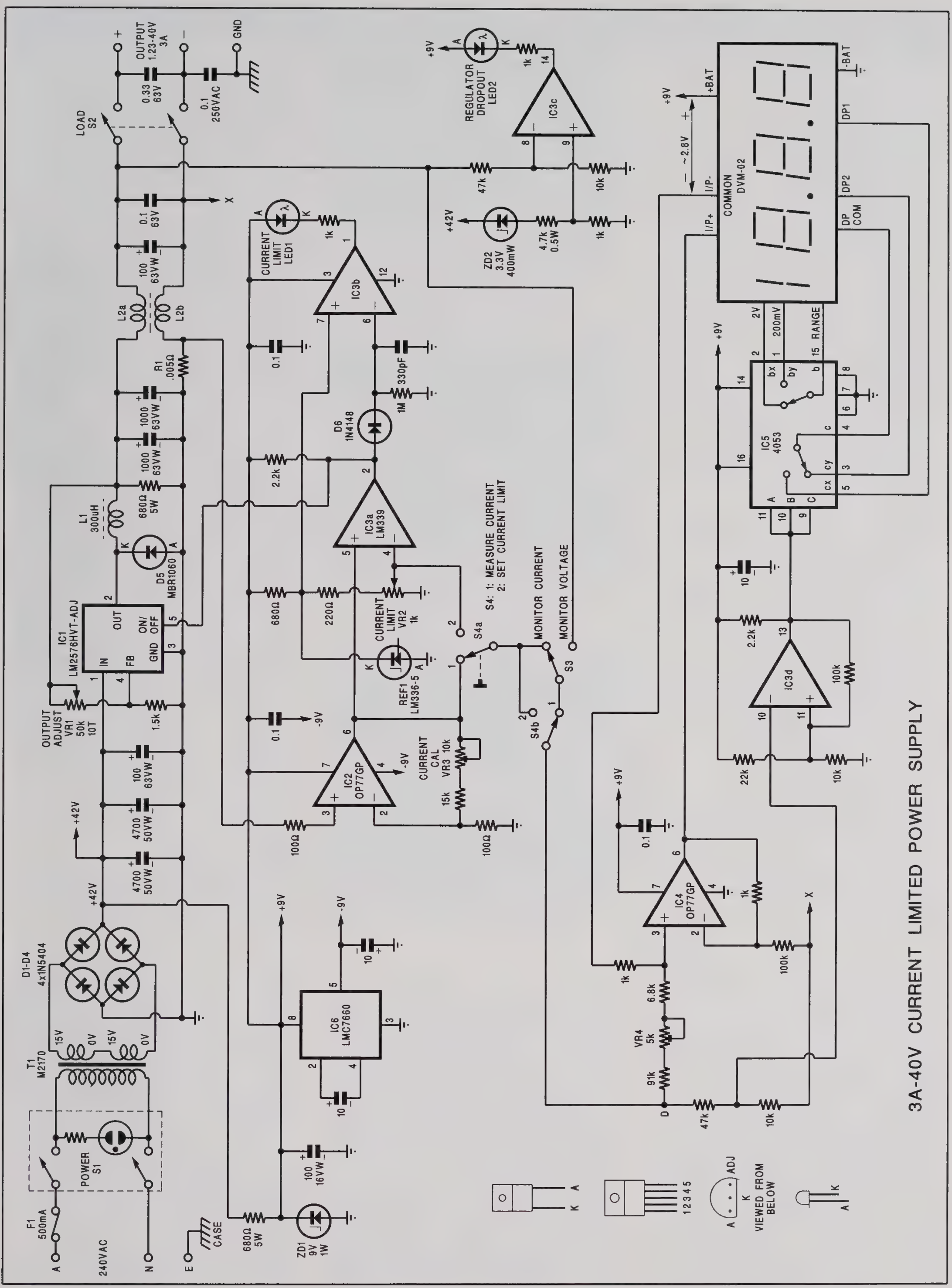
As shown in Fig.5, L2a is used to decouple the positive supply rail, while L2b decouples the negative rail. The inductor thus effectively filters any common mode signals, while the 100µF and 0.1µF capacitors across the output attenuate any remaining spikes.

The resulting filtered voltage is then applied to the output terminals via load switch S2. Additional filtering is applied at this point using a 0.33µF capacitor across the terminals and a 0.1µF capacitor between the negative terminal and mains ground. Note that this 0.1µF capacitor must be rated at 250VAC to comply with safety standards.

Regulator dropout

Comparator IC3c and its associated parts form the regulator dropout indicator depicted on the block diagram. In this circuit, a sample of the output voltage is applied to pin 8 of IC3c and compared with a sample of the regulator input voltage at pin 9. Zener diode ZD2 provides an offset, so that IC3c only switches its output (pin 14)

Fig.5 (right): the main switching regulator circuit is based on IC1, L1 & D5, while IC2, IC3a & VR2 control the ON/OFF input of IC1 to provide the current limit feature. IC4 provides signal conditioning for the DVM-02 panel meter, with IC3d & IC5 providing automatic range switching.



OUTPUT 1.23-40V 3A
GND
LOAD S2
0.33 63V
0.1 250VAC
0.1 63V
100 63VW
L2a
L2b
R1 .005Ω
1000 63VW
680Ω 5W
L1 300uH
D5 MBR1060
IC1 LM2576HVT-ADJ
IN
FB
GND
OUT
ON/OFF
OUTPUT ADJUST VR1 50k 10T
1.5k
4700 50VW
+42V
D1-D4 4x1N5404
T1 M2170
15V
0V
POWER S1
F1 500mA
240VAC
A
N
E
CASE
680Ω 5W
ZD1 9V 1W
100 16VW
+9V
-9V
IC6 LMC7660
10
CURRENT LIMIT LED1
IC3b
IC3a LM339
IC3c
330pF
1M
D6 1N4148
2.2k
680Ω
220Ω
CURRENT LIMIT VR2 1k
REF1 LM336-5
IC2 OP77GP
CURRENT CAL VR3 10k
15k
100Ω
REGULATOR DROPOUT LED2
47k
10k
ZD2 3.3V 400mW
4.7k 0.5W
1k
S4: 1: MEASURE CURRENT
2: SET CURRENT LIMIT
S4a
S4b
S3
MONITOR CURRENT
MONITOR VOLTAGE
DVM-02
+BAT
-BAT
~2.8V
I/P-
I/P+
COMMON
DP1
DP2
DP COM
2V
200mV
RANGE
IC5 4053
IC3d
22k
100k
IC4 OP77GP
VR4 5k
6.8k
91k
X
D
VIEWED FROM BELOW
ADJ
K
A
12345

3A-40V CURRENT LIMITED POWER SUPPLY

Parts List

1 PC board, code 04202941, 222 x 160mm
1 front panel label, 250 x 75mm
1 plastic instrument case with aluminium front & rear panels, 260 x 190 x 80mm
1 M-2170 30V 100VA mains transformer (Altronics)
1 LCD voltmeter module (Altronics Cat. Q-0560)
3 captive head binding posts (1 red, 1 black, 1 green)
1 2AG panel-mount safety fuseholder
1 500mA 2AG fuse
1 TO-220 heatsink, 26 x 30 x 15mm (Jaycar Cat. HH-8504)
1 SPDT mains rocker switch with neon indicator (S1)
1 DPDT paddle switch (S2) (DSE P-7693 or equiv.)
1 SPDT toggle switch (S3)
1 DPDT momentary pushbutton switch with common terminal at side (S4) (Altronics S-1394)
1 ETD29 transformer assembly with 3C85 core (Philips: 2 cores 4312 020 3750 2; 1 former 4322 021 3438 1; 2 clips 4322 021 3437 1)
1 RCC32.6/10.7, 2P90 ring core (Philips 4330 030 6035)
2 15mm diameter knobs
1 mains cord & plug
1 cord grip grommet
2 5mm LED bezels
26 PC stakes
5 self-tapping screws to mount PC board
2 4mm screws nuts & washers
4 3mm screws, nuts & star washers
1 3mm countersunk screw, nut & star washer (use a dress screw if the front panel is screen printed)
6 crimp lug eyelets for 3mm screw
2 solder lugs for 9mm thread
1 TO-220 insulating bush & washer
12 cable ties
1 50kΩ 10-turn pot (VR1)
1 1kΩ linear pot (VR2)
1 10kΩ horizontal trimpot (VR3)
1 5kΩ horizontal trimpot (VR4)

Wire & cable
1 2-metre length of 1.5mm enamelled copper wire
1 3.5-metre length of 0.8mm enamelled copper wire
1 60mm length of 0.4mm enamelled copper wire
1 200mm length of 0.8mm tinned copper wire
1 25mm length of 1.0mm enamelled wire (for use as a feeler gauge)
1 600mm length green/yellow mains wire
1 1.5-metre length of red hook-up wire
1 1.5-metre length of black hook-up wire
1 1.5-metre length of green hook-up wire
1 1.5-metre length of blue hook-up wire
1 200mm length of 3-way rainbow cable
1 200mm length of red 32 x 0.20mm hook-up wire
1 200mm length of black 32 x 0.20mm hook-up wire

Semiconductors
1 LM2576HVT-ADJ high voltage adjustable switchmode voltage regulator (IC1) (NSD)
2 OP77GP op amps (IC2,IC4)
1 LM339 quad comparator (IC3)
1 4053 CMOS switch (IC5)
1 LMC7660 switched capacitor voltage converter (IC6)
4 1N5404 3A 400V diodes (D1-D4)
1 MBR1060 Schottky diode (D5)
1 1N4148 signal diode (D6)
1 9V 1W zener diode (ZD1)
1 3.3V 400mW zener diode (ZD2)
1 LM336-5 5V reference (REF1)
2 5mm red LEDs (LED1,LED2)

Capacitors
2 4700µF 50VW electrolytic
2 1000µF 63VW electrolytic
2 100µF 63VW electrolytic
1 100µF 16VW electrolytic
3 10µF 16VW electrolytic
1 0.33µF 63VW MKT polyester
4 0.1µF 63VW MKT polyester
1 0.1µF 250VAC polyester
1 330pF MKT polyester

Resistors (0.25W, 1%)
1 1MΩ
2 100kΩ
1 91kΩ
2 47kΩ
1 22kΩ
1 15kΩ
3 10kΩ
1 6.8kΩ
1 4.7kΩ 0.5W
2 2.2kΩ
1 1.5kΩ
5 1kΩ
1 680Ω
2 680Ω 5W
1 220Ω
2 100Ω

Miscellaneous
Insulating tape, solder, heatshrink tubing, heatsink compound, 4.7Ω 5W resistor (for load testing).

low when the voltage across the regulator drops below 3.3V.

In this situation, IC1 is no longer regulating and IC3c lights LED 2 to provide a warning that the supply has dropped out of regulation.

Current limiting

The current sense resistor (R1) is wired into the negative supply rail before L2b and consists of a short length of 0.4mm enamelled copper wire. As explained previously, the voltage across it is multiplied by 200 using IC2, so that IC2's output delivers 1V per amp of load current.

In this application, IC2 must have low input offset voltage and input bias current specifications. This is necessary to ensure that IC2's output will be at 0V when no current is flowing through R1. The OP77GP used here typically has an input offset voltage of just 50µV and an input bias current of just 1.2nA.

Because its inputs operate at close to ground potential, IC2 must be powered from both positive and negative supply rails. The positive supply rail for IC2 (and for the remaining ICs) is derived from the output of the bridge rectifier via a 680Ω resistor and 9V zener diode ZD1. IC6, an LMC7660 switched capacitor voltage converter, generates the -9V rail for IC2.

In operation, IC6 first charges the 10µF capacitor between pins 2 & 4 to 9V. It then reverses the connections of the capacitor so that it can charge a second 10µF capacitor at pin 5 with negative polarity. This process is repeated continuously at a rate of about 10kHz so that the resulting output is a relatively smooth DC voltage.

Comparator stage IC3a monitors the

output voltage from IC2 and compares this with the voltage on its inverting input, as set by current limit control VR2. This potentiometer and its associated 220Ω resistor form a voltage divider network which is connected across 5V reference REF1. In operation, VR2 sets the voltage on pin 4 of IC2 at between 0V and 4V, corresponding to current limit settings of 0-4A.

Because IC3a is an open collector device, its output at pin 2 is connected to the positive supply rail via a 2.2kΩ pull-up resistor. If the voltage at the output of IC2 is greater than that set by VR2, pin 2 of IC3a is pulled high by this resistor. This also pulls pin 5 of IC1 high and switches off the regulator to provide current limiting. At the same time, pin 6 of IC3b is pulled high via D6, and so pin 1 switches low and LED 1 lights to indicate current limiting.

When the current subsequently falls below the preset limit, pin 2 of IC3a switches low again and the regulator turns back on. Thus, IC3a switches the regulator on and off at a rapid rate to provide current limiting, as described previously. The 1MΩ resistor and 330pF capacitor at pin 6 of IC3b provide a small time delay so that LED 1 is powered continuously during current limiting.

Digital panel meter

IC4 forms the basis of the signal conditioning circuit. This op amp is wired in differential mode and operates with a gain of 0.01, as set by the resistor feedback networks on pins 2 and 3. Its output appears at pin 6 and is applied to the I/P+ input of the digital voltmeter (DVM-02).

The DVM-02 is a standard panel meter with differential inputs (I/P+ and I/P-) and requires a 9V power supply between its BAT + and BAT- terminals. Its I/P- input is fixed at 6.2V (ie, 2.8V below the positive supply) and this reference voltage is used to bias pin 3 of IC4 via a 1kΩ resistor. This bias produces an offset at the output of IC4 and ensures that the voltage fed to the digital voltmeter is within its operating range.

This signal conditioning is necessary because the DVM-02 cannot be used to directly measure voltages within 1V of either supply rail.

The voltage range of the DVM-02 is selected by bridging pads on the voltmeter PC board. In this case, only the 200mV and 2V ranges are used. The decimal point is selected in a similar manner (ie, by bridging DP1 or DP2 to DP COM).

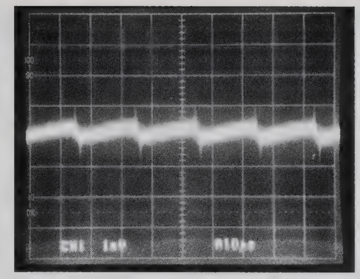


Fig.6: this scope photograph shows 100Hz ripple at the output terminals of the power supply when driving a 3A load at 12V.

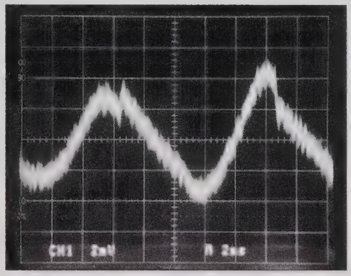


Fig.7: this is the 100Hz ripple for a 3A at 24V. Note the increase in ripple with the higher voltage.

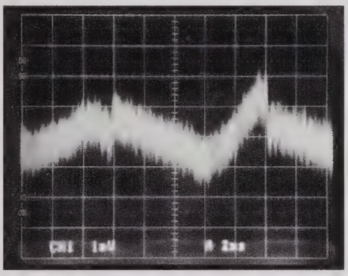


Fig.8: this is the high frequency switching noise as seen on a 100MHz oscilloscope using a 10:1 probe.

In operation, switch S3 selects either the positive output rail or the output of IC2 to provide voltage or current measurement, respectively. The resulting voltage signal on the wiper of S4b is then applied to pin 3 of IC4 via VR4 and its associated series resistors. Alternatively, pressing S4 applies the voltage on the wiper of VR2, so that the current limit reading will be displayed on the DVM-02. This occurs regardless of the setting of S3.

In summary then, IC4 divides the voltage at point D by 100 and adds this to the 6.2V reference signal. Thus, if we are measuring an output voltage of 20V for example, IC4's output will be at 6.2 + 20/100 = 6.4V. This is 200mV greater than the reference voltage at I/P- which means that the meter will display 20.0 – assuming suitable range and decimal point switching.

Range switching

IC3d and IC5 provide the range and decimal point switching, so that this operation is completely automatic. IC3d is wired as a Schmitt trigger and monitors the voltage between point D and the negative output rail (point X) via a voltage divider (47kΩ and 10kΩ).

IC3d's output drives the A, B and C inputs of IC5, a 3-pole 2-way CMOS analog switch. In this application, one switch pole (pole 'b') is used for range selection and another (pole 'c') for decimal point selection. The third switch pole is left unused.

When the voltage at D is less than 18V, IC3d's output is pulled high and pole 'b' connects to the 'by' position so that the 200mV range is selected. At the same time, pole 'c' connects to the 'cy' position so that decimal point DP2 is selected. This allows the display to read from 0.00 to 18.00 volts (approx.) with 10mV resolution.

However, if the voltage at point D rises above 18V, the output of IC3d switches low and so the A, B & C inputs of IC5 also go low. Pole 'b' now connects to the 'bx' position and pole 'c' to the 'cx' position, so that the 2V range and decimal point DP1 are now selected. The display can now read from 18.0 to 40.0 volts with 100mV resolution (note: the most significant digit is not used in this mode).

Because Schmitt trigger IC3d operates with about 3V of hysteresis (as set by the 100kΩ feedback resistor), the voltage at point D must now drop below about 15V before pin 13 switches high again to select the 200mV range on the DVM-02. The voltage at point D must then be increased above 18V again to select the 2V range. This small amount of hysteresis prevents display jitter at settings close to the range changeover point.

That completes the circuit description. The full constructional details are in the following article. **SC**

SILICON CHIP
3A-40V ADJUSTABLE POWER SUPPLY
POWER
31.1
CURRENT LIMIT
SET
OVERLOAD
A
V
METER
DROPOUT
LOAD
VOLTAGE ADJUST

40V 3A variable power supply; Pt.2

In this article, we complete the 3A-40V Adjustable Power Supply by describing the construction, testing & setting up procedures. Most of the parts mount on a large PC board, so the assembly is straightforward.

By JOHN CLARKE

The SILICON CHIP 3A-40V Adjustable Power Supply is housed in a standard plastic instrument case measuring 260 x 190 x 80mm. This is fitted with aluminium front and rear panels, the rear panel providing the necessary heatsinking for the switching regulator (IC1). In addition, these aluminium panels are connected to the mains earth to ensure safety and play an important role in shielding the supply circuitry.

Do not, under any circumstances, use plastic panels for this project.

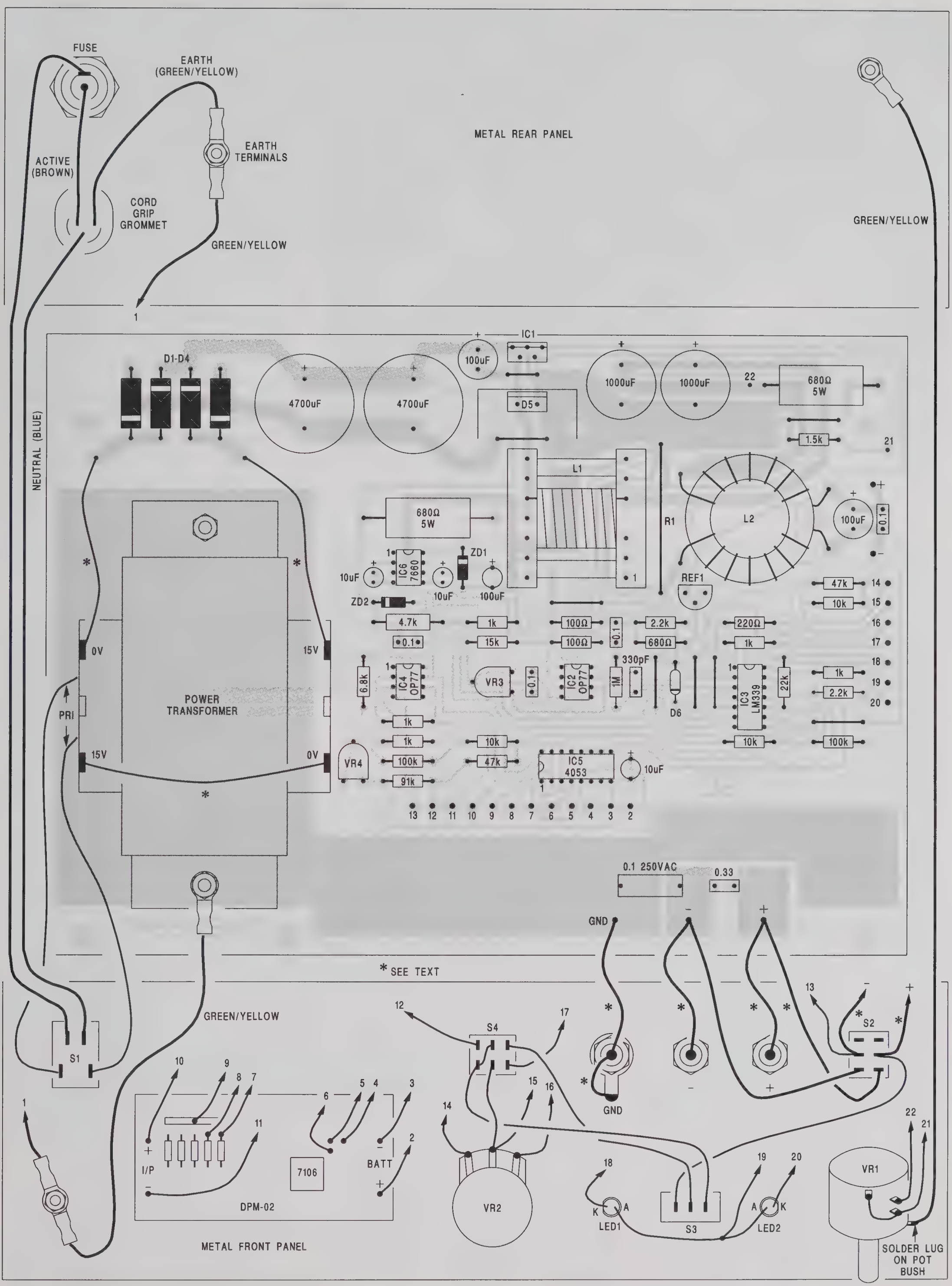
A large PC board coded 04202941 (222 x 160mm) carries the bulk of the electronic circuitry, including the power transformer. This board is mounted on pillars moulded into the base of the case and secured using self-tapping screws. Most of the remaining parts are mounted on the front panel and are connected to the PC board via insulated leads.

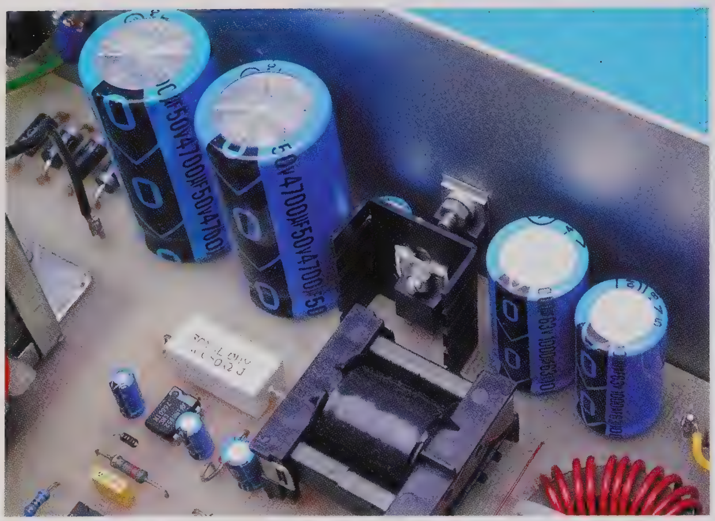
Board assembly

Fig.9 shows the parts layout on the PC board. Begin by checking the board for etching defects by comparing it with the published pattern. Usually there will be no problems but it's always best to make sure before mounting any of the parts.

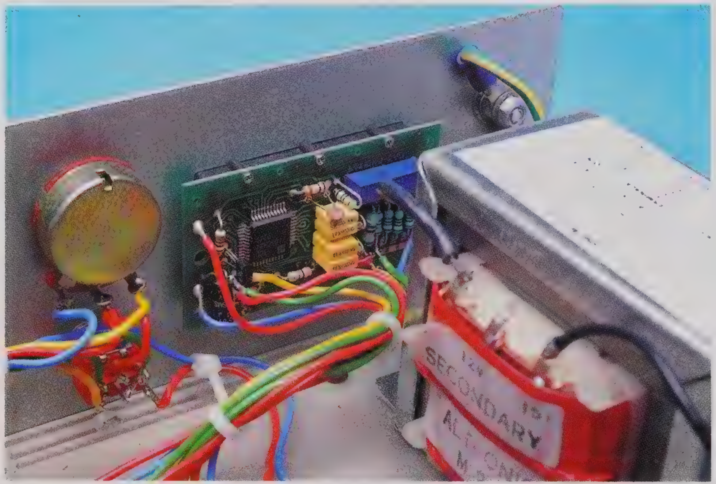
If everything is OK, start the assembly by installing PC pins at all external wiring points, then install the resistors and wire links. Table 1 lists the resistor colour codes but it's best to also check them on your multimeter as some of the colours can be difficult to decipher. Note that the two 680Ω 5W resistors should be mounted about 1mm above the board to allow air circulation, while the 4.7kΩ resistor

Fig.9 (facing page): install the parts on the PC board as shown on this combined layout & wiring diagram. The leads marked with an asterisk (*) must be run using 32 x 0.2mm wire in order to carry the heavy currents involved. ▶


FUSE
EARTH (GREEN/YELLOW)
METAL REAR PANEL
EARTH TERMINALS
ACTIVE (BROWN)
CORD GRIP GROMMET
GREEN/YELLOW
GREEN/YELLOW
1
NEUTRAL (BLUE)
D1-D4
4700uF
4700uF
100uF
IC1
1000uF
1000uF
22
680Ω 5W
D5
1.5k
21
L1
R1
L2
100uF
0.1
680Ω 5W
IC6 7660
10uF
10uF
ZD1
100uF
ZD2
REF1
47k
14
10k
15
4.7k
1k
100Ω
2.2k
220Ω
16
0.1
15k
100Ω
0.1
680Ω
1k
17
330pF
18
6.8k
IC4 OP77
VR3
0.1
IC2 OP77
1M
D6
IC3 LM339
22k
1k
2.2k
19
20
0V
15V
PRI
POWER TRANSFORMER
15V
0V
1k
1k
10k
10k
100k
VR4
100k
47k
IC5 4053
10uF
91k
13 12 11 10 9 8 7 6 5 4 3 2
0.1 250VAC
0.33
GND
-
+
* SEE TEXT
GREEN/YELLOW
S1
12
S4
17
13
S2
-
+
10
9
8
7
6
5
4
3
11
2
+
I/P
-
7106
-
BATT
+
DPM-02
METAL FRONT PANEL
14
15
16
VR2
GND
-
+
18
K
A
LED1
S3
19
20
A
K
LED2
22
21
VR1
SOLDER LUG ON POT BUSH
1



The switching regulator (IC1) is bolted to the rear panel for heatsinking but must be isolated from the panel using an insulating bush & washer. A separate TO-220 style heatsink is fitted to diode D5.



The connections to the LCD panel meter are made by soldering leads to the terminals on the back of the PC board. Use a small fine-tipped soldering iron for this job. A few dabs of epoxy resin can be used to hold the panel meter in place.

adjacent to zener diode ZD2 must be rated at 0.5W.

The link designated R1 must be run using 0.4mm diameter enamelled copper wire (note: this is the current sense resistor). Tin each end of the link (scrape away the enamel at each end first) before mounting it on the PC board. This will ensure a good solder joint at each end of the link.

Do not use any other type of wire for this link, otherwise you will have trouble calibrating the supply later on.

Next, install the ICs, zener diodes, diodes, REF1 and the trimpots. Solder only the two outside pins of IC1 at this stage (do not trim the leads) so that it can be later easily adjusted to line up with its mounting hole in the rear panel. Make sure that the ICs and diodes are correctly oriented and be sure to use the correct part number at each location on the board. Zener diode ZD1 should be mounted with a small loop in one end to provide thermal stress relief.

Diode D5 is mounted on a small TO-220 style heatsink fitted with two locating lugs. Smear the metal tab of the diode with heatsink compound, then bolt it directly to the heatsink using a machine screw and nut (no mica washer necessary). The resulting assembly can then the fitted to the board and the leads soldered.

Note that the locating lugs on the heatsink go through two matching holes in the PC board. Bend these lugs slightly to secure the heatsink in place.

The capacitors can now all be installed on the PC board but watch the polarity of the electrolytic types. Take care when installing the three 100µF electrolytic capacitors; two of these are rated at 63VW while the third is rated at just 16VW. The latter is installed adjacent to ZD1.

Winding the transformers

Inductors L1 and L2 can now be wound and installed on the PC board.

L1 is made by winding 50 turns of 0.8mm enamelled copper wire on its plastic bobbin former. Begin by pre-tinning one end of the wire and soldering this to terminal 10. This done, wind on the first layer (with each turn adjacent to the other) and cover it with a single layer of insulation tape.

The remaining layers are then wound in exactly the same manner until 50 turns have been made, with each layer covered by a single layer of insulating tape. When the 50 turns are on, solder the wire end to terminal 4 and wind a couple of layers of tape over the completed windings.

Before assembling the transformer, the centre leg on one of the ferrite core halves must be filed down so that there is a 1mm gap between the centre cores. You will need a flat file for this job – keep the file square to the ferrite core surface to maintain an even gap across the entire face.

A short length of 1.0mm-diameter wire is used as a feeler gauge to check the gap at regular intervals. When the gap is correct, the cores can be inserted into the bobbin and the metal retaining clips snapped in place.

L2 is wound on a toroid former using two 1-metre lengths of 1.5mm enamelled copper wire – see Fig.10. There are two separate 14-turn windings, L2a and L2b, and these must be

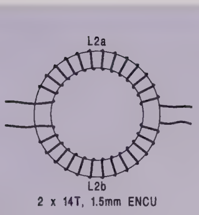


Fig.10: inductor L2 is made by winding two separate 14-turn coils on a toroid former.

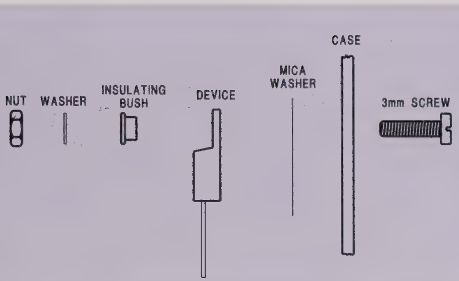


Fig.11: the mounting details for IC1. Smear all mating surfaces with thermal grease before bolting the assembly together.

wound in the directions shown to ensure correct phasing. Wind the turns on firmly and strip and tin the wire ends to ensure good solder joints to the PC board.

L1 and L2 can now both be installed as shown in Fig.9. Note that a plastic cable tie is used secure L2.

Finally, transformer T1 can be secured to the board using 4mm screws, washers and nuts.

Preparing the case

Some of the integral pillars on the base of the case must be removed in order to accommodate the PC board. To do this, first fit the board to the base and use a felt-tipped pen to mark its five mounting pillars (ie, the five directly beneath the board mounting holes). This done, remove the PC board and remove all the unused pillars using an oversize drill.

The five remaining mounting pillars should also be cut down by about 1mm, so that the transformer will fit within the case when the lid is on. In addition, the case lid has a small raised bar running across its centre and this should be removed using side cutters or a sharp chisel.

If you are building the power supply from a kit, the front and rear panels will be supplied pre-punched, while the front panel will also come with screen printed labelling. Alternatively, if you are starting from scratch, drill a mounting hole for two earth lugs in the top lefthand corner of the panel, then mount the two earth lugs using a countersunk screw plus nuts and washers (note: use a coutersunk

Reliability in signal capture.....
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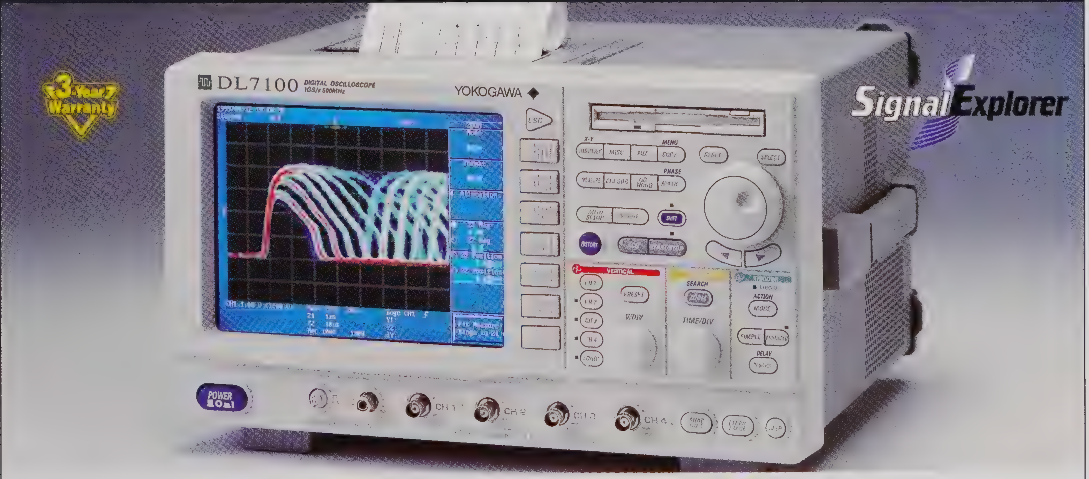

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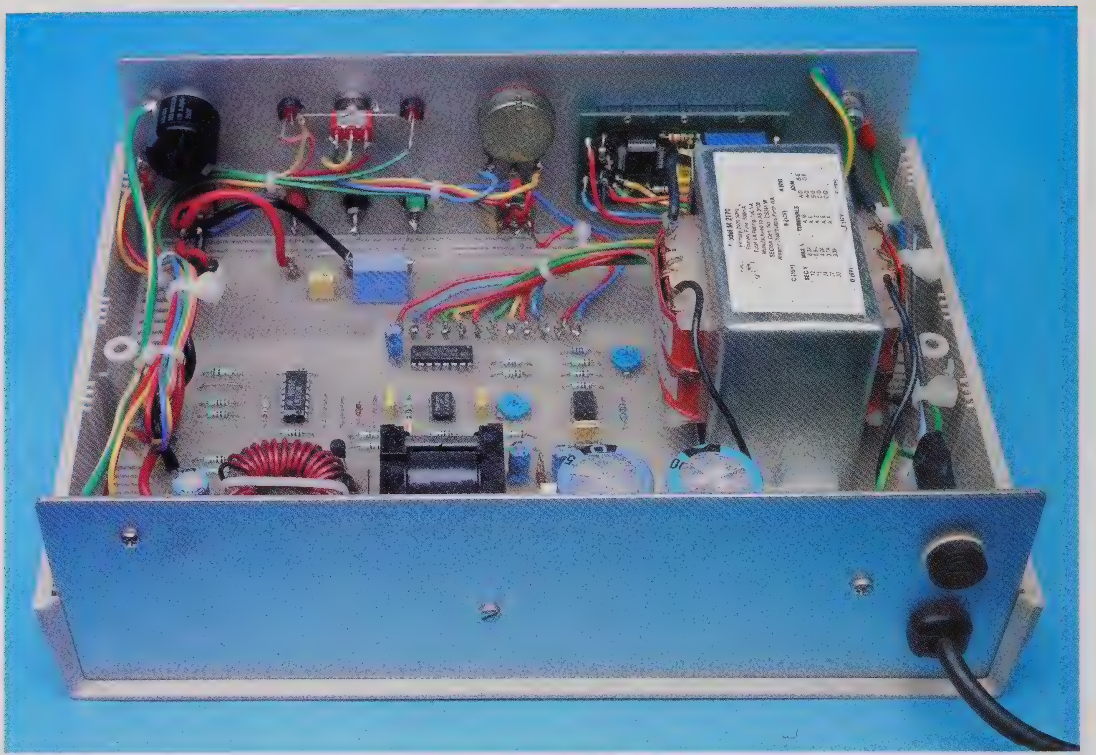


Use plastic cable ties to lace the wiring together & make sure that none of the mains leads can come adrift & short against the case or other parts. The fuse & power switch (S1) are both covered with heatshrink tubing, to prevent accidental contact with the 240V AC mains.

dress screw if the front panel is supplied screen printed).

The front panel label can now be fitted and used as a drilling template for the various holes. It's always best to drill small pilot holes first and then carefully enlarge them to size using a tapered reamer. The square cutouts for the LCD panel meter and for switches S1 and S2 can be made by first drilling a series of small holes around the inside perimeter of the marked areas, then knocking out the centre pieces and filing each cutout to shape.

The DVM-02 module is initially held in the front panel by making it a force fit, so be careful not to make its cutout too big. A small dab of epoxy resin along each side of the module (applied from the back of the front panel) is then used to secure the LCD module in position.

On the rear panel, you will need to drill holes to accept the mains fuseholder (F1), the cordgrip grommet and three solder lugs. The wiring diagram (Fig.9) shows the locations of these holes.

In addition, you will also have to drill a mounting hole for IC1. The location of this mounting hole can be determined by fitting the PC board inside the case and sliding the rear panel into position. Mark out and drill the hole, then carefully deburr it using an oversize drill so that the surface is perfectly smooth. Finally, refit the rear panel and adjust IC1 as necessary before soldering its three remaining pins to the PC board.

Fig.11 shows how IC1 is isolated from the rear panel using a mica washer and insulating bush. Smear all surfaces with heatsink compound before bolting the assembly together (note: heatsink compound is unnecessary if you use one of the new silicone impregnated washers). Finally, check that the metal tab of IC1 is indeed isolated from the rear panel using a multimeter switched to a low ohms range.

The PC board assembly can now be attached to the base of the case using five self-tapping screws and the various hardware items mounted on the front and rear panels – see Fig.9. Before mounting the potentiometers, cut the shafts to a length to suit the knobs and note that a large solder lug is fitted to the shaft of VR1. A similar large solder lug is also fitted to the GND output terminal.

Important: if the aluminium panels are anodised, you will need to scrape away the anodising from around the earth lug holes to ensure good electrical contact.

Final wiring

Fig.9 shows the final wiring details. Begin this work by stripping back the outer insulation of the mains cord by 170mm, so that the leads can reach the mains switch (S1) on the front panel. This done, push the mains cord through its entry hole and clamp it securely to the rear panel using the cordgrip grommet.

The Neutral (blue) mains lead goes directly to switch S1, while the Active (brown) lead goes to S1 via the fuse. Slide some heatshrink tubing over the leads before soldering the connections. After the connections have been made, the tubing is shrunk over the switch and fuse to prevent accidental contact with the mains.

The green/yellow striped lead from the mains cord connects directly to the rear panel earth using a crimp lug terminal. Additional green/yellow earth wires are then run from the rear panel earth to the front panel, from the front panel to the power transformer frame, and finally from the solder lug on VR1 to an earth terminal at top right on the rear panel.

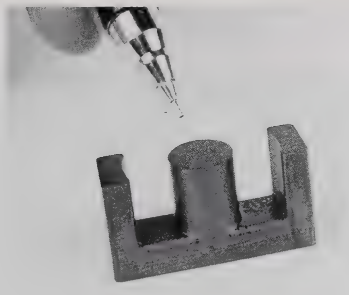
Note that the two earth leads running between the front and rear panels are critical in obtaining low residual hash in the supply output. Do not leave these leads out.

Light-duty rainbow cable is used for wiring the LEDs, while most of the remaining leads are run using light-duty hook-up wire. The exceptions are those leads marked with an asterisk (*). These must be run using 32 x 0.2mm wire in order to carry the heavy currents involved (ie, to the transformer secondary terminals, to the output terminals and to switch S2).

Note that the heavy-duty leads running from near L2 on the PC board to switch S2 are twisted to prevent noise pick-up from the switchmode circuitry. Use plastic cable ties to lace the wires together, to give a neat appearance.

In addition, use several plastic cable ties to lace the mains wires together. This is an important safety measure as it prevents any wire that may come adrift from making accidental contact with any part of the metalwork or vulnerable low-voltage circuitry.

Be warned that the wiring to switch S4 may present a few problems if the switch specified in the parts list is not used. This is because some momentary pushbutton switches have their common (C) terminals in the middle and their normally open (NO) and normally closed (NC) contacts on the out-



The centre leg on one of the ferrite core halves used for L1 must be filed down so that there is a 1mm gap between the centre cores when the inductor is assembled. The photo below shows how the ferrite core is pushed into the plastic bobbin.

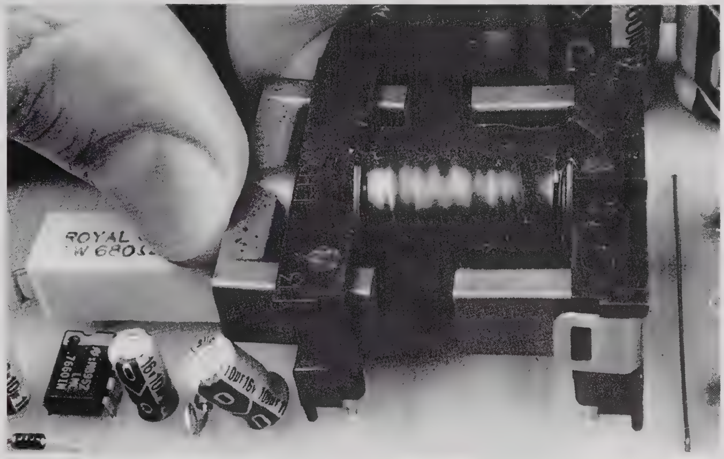


Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	1MΩ	brown black green brown	brown black black yellow brown
☐	2	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	91kΩ	white brown orange brown	white brown black red brown
☐	2	47kΩ	yellow violet orange brown	yellow violet black red brown
☐	1	22kΩ	red red orange brown	red red black red brown
☐	1	15kΩ	brown green orange brown	brown green black red brown
☐	3	10kΩ	brown black orange brown	brown black black red brown
☐	1	6.8kΩ	blue grey red brown	blue grey black brown brown
☐	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	2	2.2kΩ	red red red brown	red red black brown brown
☐	1	1.5kΩ	brown green red brown	brown green black brown brown
☐	5	1kΩ	brown black red brown	brown black black brown brown
☐	1	680Ω	blue grey brown brown	blue grey black black brown
☐	1	220Ω	red red brown brown	red red black black brown
☐	2	100Ω	brown black brown brown	brown black black black brown

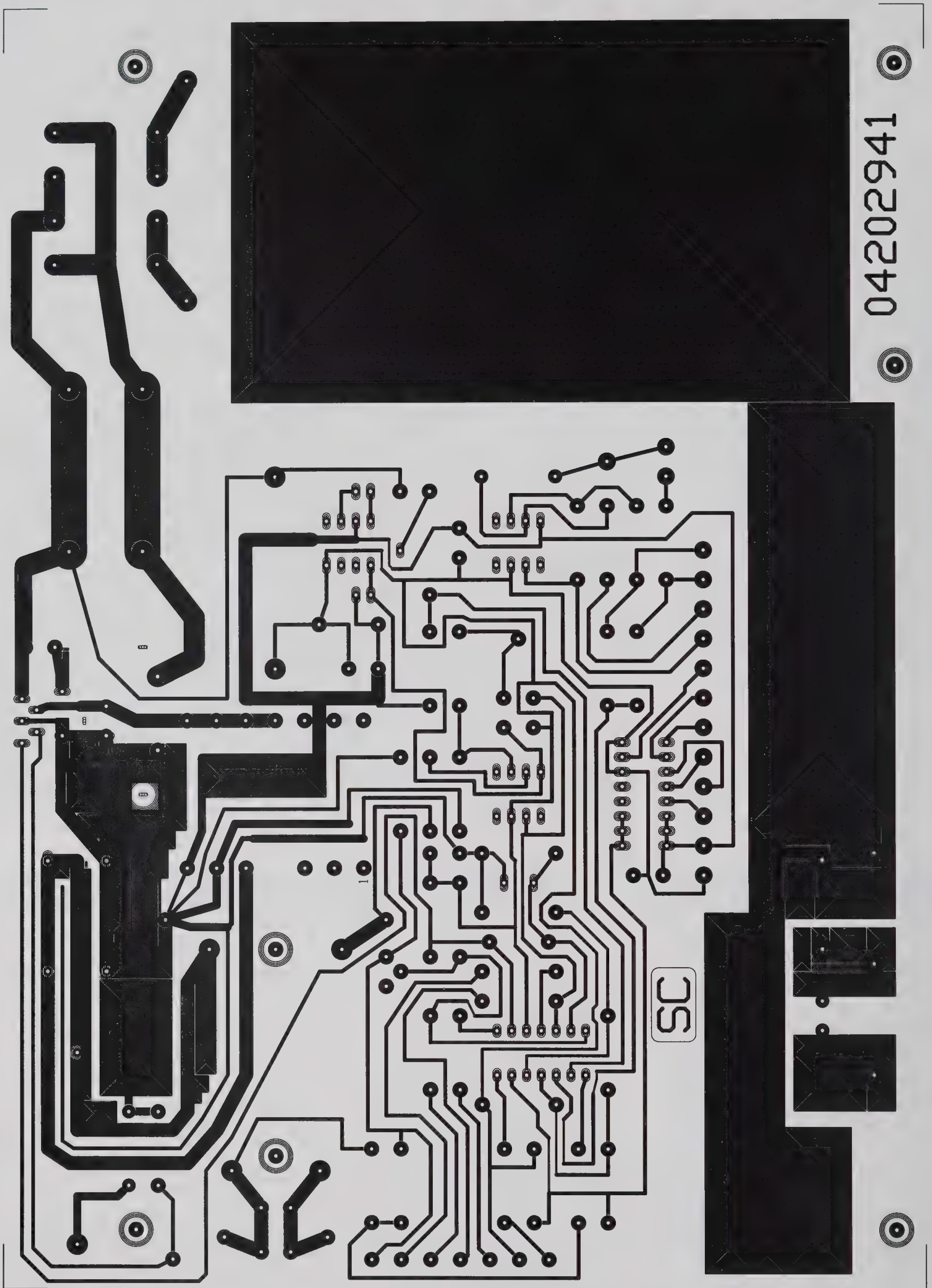


Fig.12: check your etched PC board against this full-size pattern before installing any of the parts. The board is coded 04202941 & measures 222 x 160mm.

side, whereas the switch we used has its common terminals at one end.

If your switch has its common terminals in the middle, the wiring shown in Fig.9 will no longer be relevant and you will have to work out the connections from the circuit diagram (Fig.5). The common, NO and NC terminals will usually be marked somewhere on the body of the switch.

Testing

Before applying power, carefully check your work for any wiring errors. This done, wind VR1 fully anticlockwise and set VR2, VR3 and VR4 to centre position.

Switch on the supply and immediately check that the voltage across ZD1 is about 9V. If so, check the reading on the digital display. It should show about 1.23 volts if S3 (the Meter switch) is in the "V" position, or about 0.00 amps if it is in the A position (note: the least significant digit will be incorrect until VR4 is adjusted later on).

If everything is OK at this stage, you can check the supply voltages to each IC. Connect your multimeter negative lead to the cathode of ZD1 and check the voltage at pin 7 of IC2 and IC4, pin 3 of IC3, pin 16 of IC5 and pin 8 of IC6. These should all be at +9V. Pin 4 of IC2 should be at about -9V.

If at any stage the voltages are incorrect, switch off immediately and correct the problem before proceeding.

The output voltage from the power supply should be adjustable from 1.23V up to about 43V, with the dropout LED lighting at about 42V (depending on mains voltage). Check that the voltage reading on the panel meter changes from 2-digit resolution after the decimal point to 1-digit resolution at 15-18V.

When the panel meter is set to read amps, the display may initially read several digits above or below 0.00. This can be corrected by adjusting VR4. This done, set the Current Limit control (VR2) fully anticlockwise and press the Set switch (S4). Check that the display still reads 0.00 – if not, adjust VR4 accordingly (the adjustment will only be slight).

Now press the current set switch and check that the display reading can be varied from 0.00 up to at least 4.00A by adjusting the Current Limit control. Note that the overload LED may light when the control is fully anticlockwise. This is normal and the LED will extinguish when the current limit reaches 10mA (0.01 on the display).

When measuring voltage, the panel meter should be accurate to 1% without calibration. However, if you have an accurate voltmeter, the trimpot on the back of the DVM-02 can be adjusted to give even greater accuracy if required.

For current readings, the panel meter is calibrated by first connecting a 4.7Ω 5W resistor across the output and setting the supply to deliver 4.70V. The Current Limit control should now be rotated at least half-way, to prevent the current limit feature from operating. This done, switch S3 to the "A" position and adjust VR3 until the meter shows 1.00 amps. **Warning – the resistor will become quite hot during this procedure.**

The current limiting feature should now be checked for correct operation. To do this, leave the 4.7Ω resistor in circuit and rotate the Current Limit control anticlockwise until the overload LED lights. This should initially occur at 1A but you should now be able to set lower current limits by further reducing the control setting. The power supply will squeal during current limiting but this is normal.

Finally, you can check the power supply on various loads and if you have access to an oscilloscope, you can observe the output ripple. **SC**

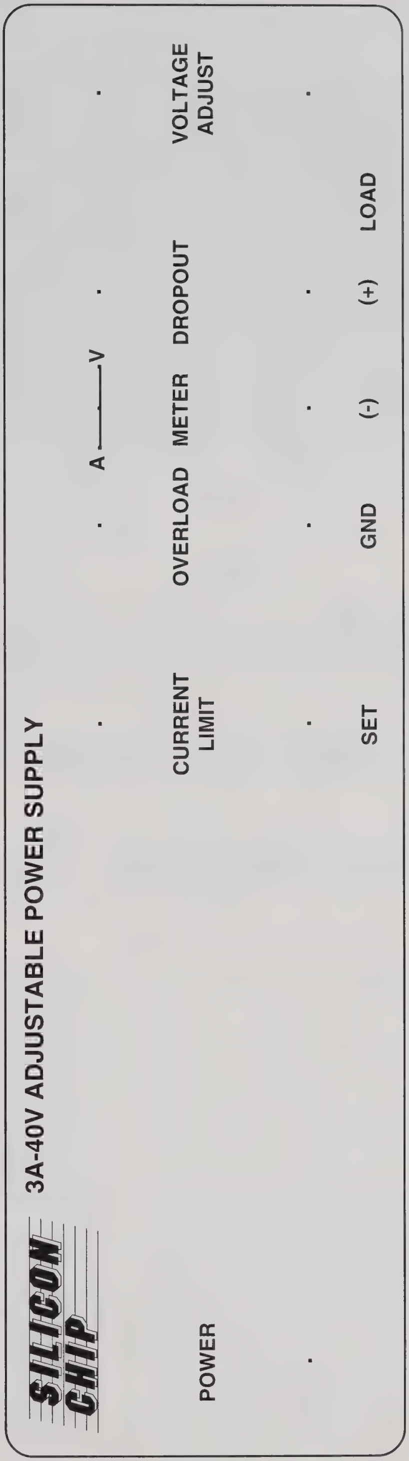


Fig.13: this full-size artwork can be used as a drilling template for the front panel. If you buy a kit, the panel will be supplied pre-punched & screen printed.

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REVIEWED BY PETER SMITH

Multisim: for advanced circuit design & simulation

OPEN ALMOST any piece of electronic equipment these days and chances are you'll see just one or two ICs, often with hundreds of pins and only a handful of discrete components. Usually, the components are so small it's difficult if not impossible to identify exactly what they are (resistor, capacitor, inductor, or what?).

It's easy to imagine the control and precision needed to assemble these miniature PC boards. What about the design of the ICs themselves though – how the heck do they design, prototype and test the circuits inside a 300-pin "mega-chip"? And how do they make sure the ICs will work in a real circuit before committing them to manufacture?

Computer software, of course, is the big answer. Ingenious software developers have been able to create virtual development environments which allow the entire design and test phase to be carried out without a piece of hardware in sight.

Bringing the design elements together in this way has less obvious advantages, too. For example, hardware engineers can work at a level of abstraction above the underlying logic elements, greatly increasing design speed.

In this review, we look at Multisim V6 from Electronics Workbench, a collection of state-of-the-art circuit design and simulation tools.

Multisim includes all the tools necessary to take a design from inception to finished project and as such, a detailed review would have to cover an enormous amount of ground. We cannot hope to do justice to all aspects of the product in this short review, so we've settled on describing some of the main features instead.

Schematic capture

Designs are drawn in a familiar Windows environment using the Schematic Capture module.

As with all other schematic capture programs, Multisim has a database of the most commonly used components (more than 16,000 in the Power-Pro edition) that can be placed and wired immediately. However, Multisim's database is perhaps unique in that every component has a simulation model attached to it (we look at simulation a little further on).

If a part that you want isn't in the database, Multisim includes a Symbol Editor that allows you to create your own, either from scratch or based on an existing component (or "symbol").

Wiring between components is a simple matter of clicking on the start and end points and Multisim makes the connection automatically. Manual control is possible too, of course. Once wires and components are placed, they can be moved by clicking and dragging.

Multisim includes a multi-level undo feature but it performs more like an "undelete" than an "undo". This means, for example, that deleted symbols and wires can be restored but operations like wire and component movement cannot be undone.

Each node in the circuit is automatically assigned a unique node number during the wiring process. Using a feature called Virtual Wiring ("virtual" because no actual interconnections are shown), it is possible to connect nodes together by manually assigning the same node numbers. Typically, the supply rails in a circuit are connected in this way, resulting in less clutter and better readability.

Readability is also one of the aims of Multisim's subcircuit feature. A section or entire page of an existing circuit can be defined as a subcircuit and then used within another circuit. An optional add-on module expands the functionality of subcircuits even further, allowing them to be saved and edited just like any other schematic file.

Completed schematics can be exported in variety of formats to suit all major PC board layout software packages. However, the transition to PC board layout is much smoother when using the Electronics Workbench product – Ultiboard. This is because Ultiboard recognises information from Multisim like component footprints and minimum track widths (gleaned during simulation) without modification.

Types of simulation

As we mentioned earlier, simulation provides a means of examining circuit behaviour without having to physically construct it. Before we look at how a simulation is performed in Multisim, let's touch briefly on the technologies involved.

Multisim supports three different simulation technologies – SPICE, VHDL and Verilog.

SPICE is an analog circuit simulator, the core (or kernel) of which has become an industry standard since its release to the public domain in 1972. A number of companies offer SPICE simulators that expand on the functionality and feature set of the original release. A notable example is XSPICE, which provides extensions for digital logic simulation. Multisim includes support for all of the most popular SPICE extensions.

SPICE, by the way, is an acronym for Simulation Program with Integrated Circuit Emphasis!

VHDL and Verilog are hardware description languages (HDLs) that are used to both document and design electronic systems.

VHDL was born out of a US Defence Department contract and since its release in 1985, has been standardised by the IEEE (Institute of Electrical and Electronics Engineers). Verilog started life as a proprietary hardware modelling language and in 1990, it too was released to the public domain and standardised by the IEEE.

VHDL and Verilog provide a means of designing and simulating complex digital logic, especially Complex Programmable Logic Devices (CPLDs) and Field Programmable Gate Arrays (FPGAs). Devices like our imaginary 300-pin "mega-chip" are designed using these languages.

It is important to note that VHDL and Verilog are behavioural level languages. They describe what a circuit's inputs and outputs are, what func-

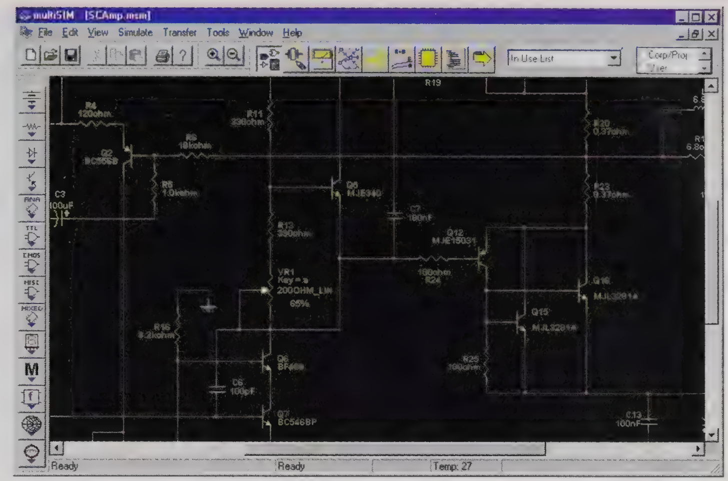

multiSIM [SCAmp.msm]
File Edit View Simulate Transfer Tools Window Help
In Use List
Corp/Proj
R4 120ohm
R11 330ohm
R19
R20 0.37ohm
R1 6.8o
Q2 BC556B
R5 18kohm
R6 1.0kohm
C3 100uF
Q8 MJE340
C7 100nF
R23 0.37ohm
R13 390ohm
Q12 MJE15031
VR1 Key = a 200OHM_LIN 65%
100ohm R24
Q16 MJL3281A
Q15 MJL3281A
R16 8.2kohm
Q6 BF469
C6 100pF
R25 100ohm
Q7 BC546BP
C13 100nF
Ready
Ready
Temp: 27

Fig.1: schematic entry and editing is a straightforward process. Fonts, colours and label positions can easily be changed for a more professional look.

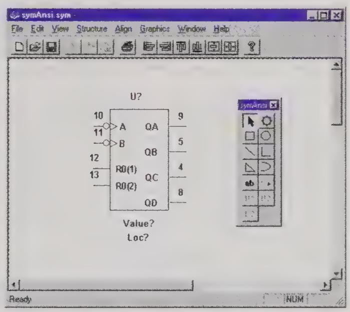
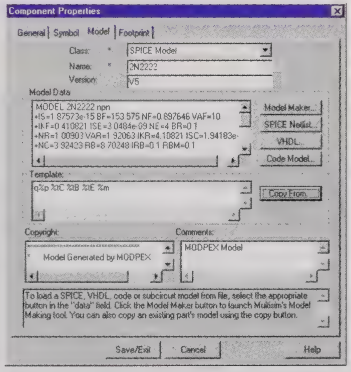

symAnsi.sym
File Edit View Structure Align Graphics Window Help
U?
10
11
A
B
12
13
R0(1)
R0(2)
QA
QB
QC
QD
9
5
4
8
Value?
Loc?
symAnsi
Ready
NUM

Fig.2: if a symbol is not in the database, it can be created from scratch or an existing symbol can be modified using the Symbol Editor.


Component Properties
General
Symbol
Model
Footprint
Model Maker...
SPICE Netlist...
VHDL...
Code Model...
Copy From...
Save/Exit
Cancel
Help

Class: * SPICE Model

Name: * 2N2222

Version: V5

Model Data:

```
MODEL 2N2222 npn
+IS=1.87573e-15 BF=153.575 NF=0.897646 VAF=10
+IKF=0.410821 ISE=3.0484e-09 NE=4 BR=0.1
+NR=1.00903 VAR=1.92063 IKR=4.10821 ISC=1.94183e-
+NC=3.92423 RB=8.70248 IRB=0.1 RBM=0.1
```

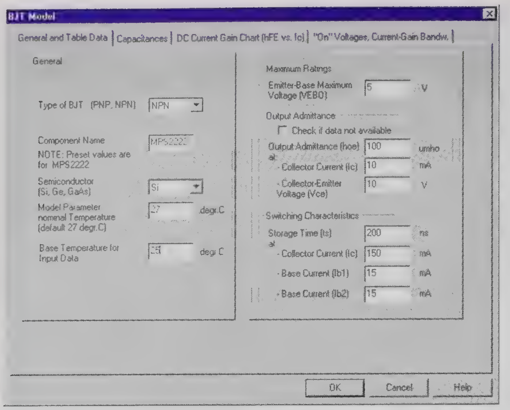
Template: q%p %tC %tB %tE %m

Copyright: Model Generated by MODPEX

Comments: MODPEX Model

To load a SPICE, VHDL, code or subcircuit model from file, select the appropriate button in the "data" field. Click the Model Maker button to launch Multisim's Model Making tool. You can also copy an existing part's model using the copy button.

Fig.3: to access simulation model information, it's just a matter of right-clicking on the component and choosing properties. Models can be created or imported from the model tab.


BJT Model
General and Table Data
Capacitances
DC Current Gain Chart (hFE vs. Ic)
"On" Voltages, Current-Gain Bandw.
General
Maximum Ratings
Output Admittance
Switching Characteristics
OK
Cancel
Help

Type of BJT (PNP, NPN): NPN

Component Name: MPS2222

NOTE: Preset values are for MPS2222

Semiconductor (Si, Ge, GaAs): Si

Model Parameter nominal Temperature (default 27 degr.C): 27 degr.C

Base Temperature for Input Data: 25 degr.C

Emitter-Base Maximum Voltage (VEBO): 5 V

☐ Check if data not available

Output Admittance (hoe): 100 umho

at: - Collector Current (Ic): 10 mA

- Collector-Emitter Voltage (Vce): 10 V

Storage Time (ts): 200 ns

at: - Collector Current (Ic): 150 mA

- Base Current (Ib1): 15 mA

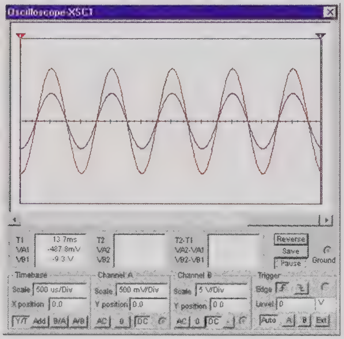
- Base Current (Ib2): 15 mA

Fig.4: using Model Makers to create a simulation model from the manufacturer's data sheets. In this example, we have chosen to make a BJT (Bipolar Junction Transistor) model. Model Makers supports many other model "classes", including diodes, MOSFETs, SCRs, op amps, strip lines, waveguides, etc.

tions are performed in the middle and how long it all takes to happen. By contrast, when talking about digital logic, SPICE could be described as a transistor/gate level language.

Multisim provides simulation engines for all three of these standards and what's more, they can work together to co-simulate an entire mixed mode analog and digital circuit at the board level.

This is a big advance, as separate simulators (often from different companies) were previously needed to simulate mixed mode circuits – and they rarely talked to one another!


Oscilloscope-XSC1
Reverse
Save
Pause
Ground
Timebase
Channel A
Channel B
Trigger
Y/T
Add
B/A
A/B
AC
0
DC
Auto
A
B
Ext

T1: 13.7ms

VA1: -487.8mV

VB1: -9.3 V

T2

VA2

VB2

T2-T1

VA2-VA1

VB2-VB1

Timebase Scale: 500 us/Div

X position: 0.0

Channel A Scale: 500 mV/Div

Y position: 0.0

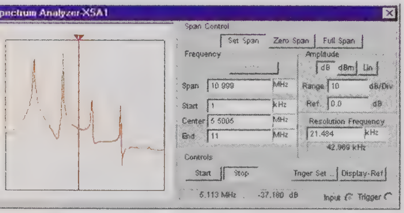
Channel B Scale: 5 V/Div

Y position: 0.0

Trigger Edge

Level: 0 V

Fig.5: view from the drivers seat – the virtual oscilloscope.


pectrum Analyzer-XSA1
Span Control
Set Span
Zero Span
Full Span
Frequency
Amplitude
dB
dBm
Lin
Controls
Start
Stop
Triger Set ..
Display-Ref
Input
Trigger

Span: 10.999 MHz

Start: 1 kHz

Center: 5.5005 MHz

End: 11 MHz

Range: 10 dB/Div

Ref.: 0.0 dB

Resolution Frequency: 21.484 kHz

42.969 kHz

5.113 MHz   -37.180 dB

Fig.6: this spectrum analyser costs a lot less than its real world equivalent!

More about models

We mentioned that all components in the database are associated with a simulation model. Simply put, these models "tell" the simulator how components work.

Multisim supports SPICE, VHDL, and Verilog models. In addition, where a ready-defined model isn't available, Multisim provides a feature called Model Makers. This feature allows you to build an accurate simulation model (analog or digital) directly from the manufacturer's data sheets. And if that's not enough, circuits can be modelled at behavioural level using the C programming language – Multisim calls this Code Modelling. Whew!

So, a simulator "knows" about components in a circuit by interpreting their respective models. But how do we "see" what the simulator is doing?

Simulation in action

To examine the operation of a prototype circuit we have constructed, we would apply appropriate stimulus to the input and view the results at the output. In a Multisim simulation, we do exactly the same thing, except that all our instruments are "virtual".

Multisim includes a whole host of virtual instruments that function just like their real-world counterparts. These include an oscilloscope, spectrum analyser, logic analyser, wattmeter, distortion analyser, network analyser, Bode plotter, function generator, word generator and of course a multimeter.

Forget hunting for those missing test leads – simply drop your virtual instrument of choice onto the schematic and wire it in! Double-clicking on the instrument icon brings up its display and control panel, with mouse-activated knobs and switches.

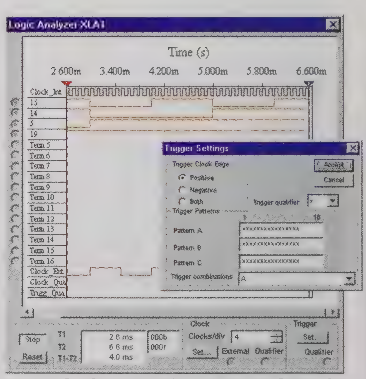
In addition to the function generator and word generator instruments, Multisim provides other means of applying stimulus to your circuits. A whole class of components called "sources" generate AC and DC currents and voltages, as well as clocks, pulses, one-shots, etc. Specialist AM and FM modulated sources for radio frequency design are also included. The parameters for each source (amplitude, frequency, etc) are controllable via their property pages.

Well, this probably all sounds just too complex if you are a beginner to electronics. Connecting a logic analyser to a 2-chip counter circuit may seem like overkill but Multisim has the bases covered here, too. A class of components called "indicators" provides a voltmeter, ammeter, logic probe, hex display, lamp and bargraph, all of which operate like their real-world cousins. For example, the buzzer sounds the PC speaker and the hex display segments "light up" in line with their logic inputs.

While simulating a high-power audio amplifier circuit, I unexpectedly discovered that Multisim's fuses actually go open-circuit when their ratings are exceeded. However, as far as I know, Multisim doesn't include sound effects or burning smells!

Virtual components

With the circuit complete and in-


Logic Analyzer-XLA1
Time (s)
2.600m
3.400m
4.200m
5.000m
5.800m
6.600m
Clock_Int
15
14
5
19
Term 5
Term 6
Term 7
Term 8
Term 9
Term 10
Term 11
Term 12
Term 13
Term 14
Term 15
Term 16
Clock_Ext
Clock_Qua
Trigg_Qua
Trigger Settings
Accept
Cancel
Stop
Reset
Clock
Set...
External
Qualifier
Trigger
Set.
Qualifier

Trigger Clock Edge: ● Positive ○ Negative ○ Both

Trigger qualifier: x

Trigger Patterns

Pattern A: xxxxxxxxxxxxxxxx

Pattern B: xxxxxxxxxxxxxxxx

Pattern C: xxxxxxxxxxxxxxxx

Trigger combinations: A

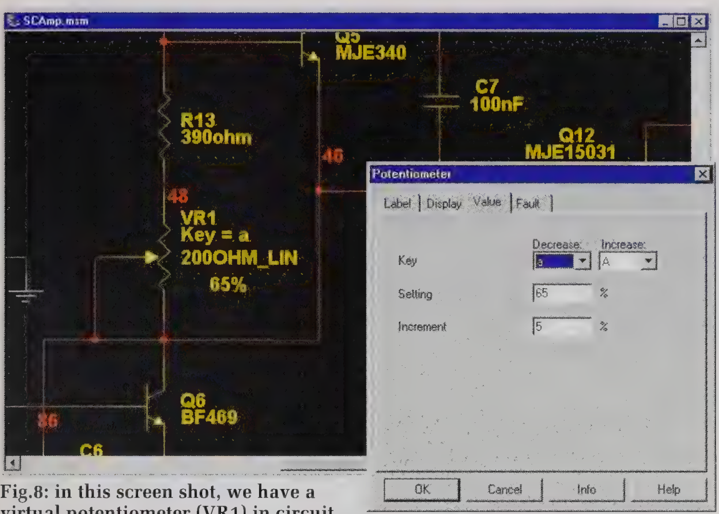
T1: 2.6 ms 000b

T2: 6.6 ms 000f

T1-T2: 4.0 ms

Clocks/div: 4

Fig.7: the logic analyser is another of Multisim's virtual instruments. Setting up triggers couldn't be simpler.


SCAmp.msm
Q5
MJE340
C7
100nF
R13
390ohm
46
Q12
MJE15031
48
VR1
Key = a
200OHM_LIN
65%
Q6
BF469
36
C6
Potentiometer
Label
Display
Value
Fault
OK
Cancel
Info
Help

Key — Decrease: a — Increase: A

Setting: 65 %

Increment: 5 %

Fig.8: in this screen shot, we have a virtual potentiometer (VR1) in circuit. The properties page shows that it is increased and decreased with the "a" and "A" keys, with each keystroke varying the value by 5%.

struments and sources connected and configured, it's then just a matter of hitting the simulate switch to start the simulation running.

One of the features I really like here is the ability to change component values in the circuit without even having to stop the simulation. This is achieved by temporarily substituting any components you would like to vary with their "virtual" equivalents. Virtual components (resistors, capacitors and inductors) can be increased or decreased in value in real time by hitting certain keys on your keyboard – you decide which.

Naturally, the property pages for virtual components allow setting things like the initial value and the percentage change with each keystroke, etc.

Circuit analysis

We've talked about how Multisim's circuit simulator can display real-time results on virtual instruments but it is capable of far more. Using the SPICE simulation engine, many different types of analyses can be performed. These include DC operating point, transient, AC frequency sweep, Fourier analysis and noise and distortion, to name a few. The results from these analyses are automatically graphed and can be exported to other applications such as Excel or Mathcad.

Analyses results can be handed to the Postprocessor module, which performs mathematical wizardry according to your requirements and plots the results on a chart or graph. Types of mathematical operations include arithmetic, trigonometric, exponential, logarithmic, complex, vector, etc.

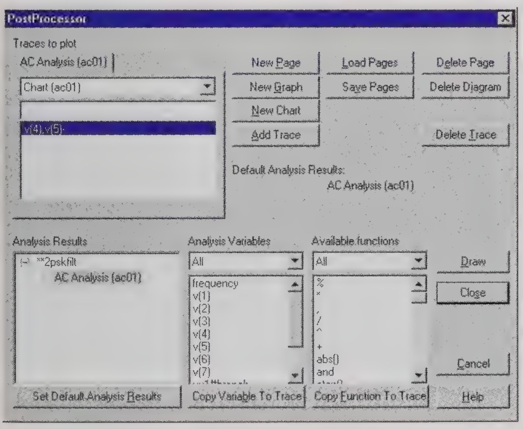

PostProcessor
Traces to plot
AC Analysis (ac01)
Chart (ac01)
v(4)-v(5)
New Page
Load Pages
Delete Page
New Graph
Save Pages
Delete Diagram
New Chart
Add Trace
Delete Trace
Default Analysis Results:
AC Analysis (ac01)
Analysis Results
**2pskfilt
AC Analysis (ac01)
Analysis Variables
All
frequency
v(1)
v(2)
v(3)
v(4)
v(5)
v(6)
v(7)
Available functions
All
%
*
/
^
+
abs()
and
Draw
Close
Cancel
Help
Set Default Analysis Results
Copy Variable To Trace
Copy Function To Trace

Fig.9: the Postprocessor can act on results from an analysis using a variety of mathematical operations. The results can then be displayed as a graph or table, or simply exported to Excel or Mathcad.

Programmable logic design

As the name suggests, programmable logic devices (PLDs) are ICs containing many logic gates (or building blocks) which are connected at programming time to perform the desired functions. Our imaginary "mega-chip" could be one of these.

In order to work efficiently with devices of this complexity, designers describe what they want in high level programming languages like VHDL and Verilog.

Multisim provides a complete development environment for PLDs. Using the inbuilt editor, the engineer first enters a design using the VHDL or Verilog languages. The result is then passed to the simulator, which is used to examine and debug the design. Finally, an output file is generated for programming into the target PLD.

Note that once a PLD design is complete, it can be simulated at the board level just like any other component in Multisim. The engineer would simply create a symbol for the PLD and import the VHDL/Verilog file.

If you would like to know more about VHDL or Verilog, check out the EDA industries web page at *www.eda.org*

Summary

Multisim really is an outstanding package. It excels in the simulation department, with features that would make it attractive to both professionals and educators.

Multisim is available in four editions, being Power Professional, Professional, Personal and Education – we reviewed the Power Professional edition. Not all features are available in all editions, and some tools, such as the Ultiboard PCB layout and the Programmable Logic Synthesis module must be purchased separately.

For further information or to order, visit the Emona Instruments website at *www.emona.com.au* or phone (02) 9519 3933.

Extensive information on the Multisim package can also be obtained from the Electronics Workbench website at *www.electronicsworkbench.com* **SC**

The TiePie *HANDYPROBE* HP2

Troubleshooting electrical/electronic equipment in the field can be a real pain in the proverbial. Lugging large, supposedly "portable" items of test equipment around the country can really test the nerves – as well as the muscles. Could this be the answer?

Review by PETER SMITH

AC/DC 500V MAX
HANDYPROBE
MODEL HP2
TiePie
engineering

TiePie Engineering, a Dutch company which specialises in computer controlled measuring equipment, has come up with a unique solution to the field service dilemma – the Handyprobe 2.

The Handyprobe 2 incorporates a storage oscilloscope, spectrum analyser, voltmeter and transient recorder all in a package that fits in the palm of your hand!

The probe plugs into the parallel port of any PC and in conjunction with DOS or Windows software provides a comprehensive range of data acquisition functions.

It is powered directly from the parallel port connection (no external supply or batteries are required) so is ideally suited for use with laptop computers. In fact, the probe together with its integral cable could easily slide into a spare spot in most laptop bags.

With an input range of 0.5V to 400V full scale and a maximum sampling speed of 20MHz (TiePie also produce 1,2,5 and 10MHz versions), the Handyprobe can handle just about anything you can throw at it.

To keep the cost down, TiePie have provided only single-channel acquisition in the Handyprobe 2. As with most storage 'scopes, the Handyprobe includes a reference channel that can be used to compare a stored measurement with a second (live) measurement, so a second channel is usually not required. Instrument settings can be saved and restored from disk at will.

Launching the Handyprobe 2 software displays a floating toolbar on the Windows desktop (see Fig.1). The toolbar provides access to all four of the available instruments, as well as to basic program settings (see Fig.2).

The 'scope, voltmeter and spectrum analyser instruments can all be active simultaneously, whereas the transient recorder must run independently.

Let's take a look at each of the instruments and their capabilities in a little detail.

Storage oscilloscope

TiePie boast that their instruments are "plug and measure". We connected the probe to our trusty SILICON CHIP Sine/Square Wave Generator, activated the oscilloscope and hit the Auto SET button. In less than a second the input was scaled nicely (both horizontally and vertically) and correctly triggered (see Fig.3).

Auto SET places the instrument in auto-ranging mode, so for many simple measurements you may not need to do any setup at all.

All instrument settings are available from the main toolbar via pull-down menus, with many often-used settings also controllable with single-keystroke shortcuts.

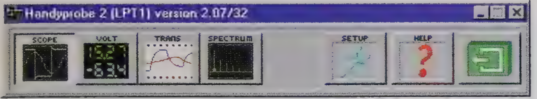
Vertical axis

The CH1 pull-down menu provides access to all vertical axis settings. Input sensitivity ranges from 0.5V to 400V full scale, configurable from the Sensitivity selection (see Fig.4). Alternatively, hitting the F5/F6 keys clicks over to the next lowest/highest setting – a bit like using that rotary switch on CRT-based oscilloscopes.

Measured values can be enlarged or reduced using the "Software Gain" function – TiePie calls this vertical axis magnification.

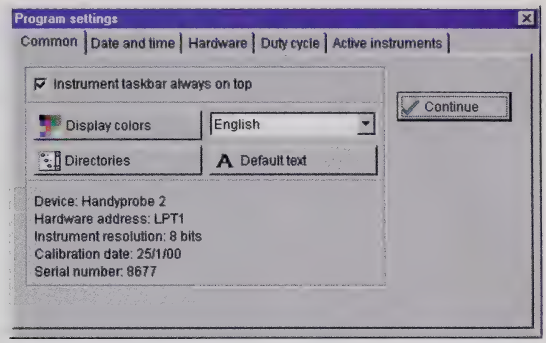
A closely related function called "Software Offset" applies a positive or negative bias to the vertical axis. Once again I was reminded of the conventional 'scope and the equivalent "position" knob (got to kick that habit). Both the Software Gain and Offset can also be changed directly on the display by clicking and dragging points on the vertical axis.

The Units of measure, Units of gain


Handyprobe 2 (LPT1) version 2.07/32

SCOPE
VOLT
TRANS
SPECTRUM
SETUP
HELP

Fig.1: the instrument toolbar provides a convenient way of activating the instruments. All except the transient recorder can be active simultaneously.


Program settings

Common
Date and time
Hardware
Duty cycle
Active instruments
Continue
Display colors
Directories
Default text

☑ Instrument taskbar always on top

English

Device: Handyprobe 2
Hardware address: LPT1
Instrument resolution: 8 bits
Calibration date: 25/1/00
Serial number: 8677

Fig.2: settings common to all instruments are accessible from the toolbar. Although not mentioned in the text, instrument calibration data can be defined on the Hardware tab.

and Units of offset functions provide for custom vertical axis marking and scaling, making tailoring for specific measuring tasks quite simple.

For example, suppose you have a temperature probe whose output changes by 1V for every 10 degrees of temperature change. By setting the Units of measure to "Degrees C" and Units of gain to "10", the vertical axis displays temperature change directly in degrees.

Other options on this menu allow choices of true or inverted signal and either AC or DC signal coupling.

Horizontal axis

Unlike its more conventional analog cousin, the digital scope's timebase is dependent on both the rate at which the incoming signal is sampled and how many samples are stored and subsequently displayed across the horizontal axis.

The Handyprobe 2 has a maximum sampling rate of 20 million samples/second and a memory depth (also called record length) of 32,760. Both the sample rate and record length are configurable from the Timebase pull-down menu (see Fig.5).

Naturally, the Handyprobe software automatically adjusts the time/div values along the horizontal axis when the sample rate and record length are changed.

Also accessible from the Timebase menu are two options that allow closer examination of any part of the acquired signal. Record View Gain provides horizontal axis magnification, whereas Record View Offset allows display of a particular section of the record.

Note the scroll bar directly below the horizontal axis – this provides a much more convenient way of panning through the record than manually entering the Record View Offset.

A feature in digital 'scopes that I've often found useful is their ability to display a number of samples prior to triggering.

On the Handyprobe, the number of pre-trigger samples can be set anywhere from zero to the maximum record size. A second scroll bar at the bottom of the display allows this value to be changed instantly.

Triggering

As expected, the Handyprobe includes variable level triggering on a rising or falling slope. Slope position, level and hysteresis can all be set from the Trigger pull-down menu. Easier still, these values can be changed by clicking and dragging the trigger symbol next to the vertical axis – too easy!

Auto level triggering is also selectable; when active an "A" is visible next to the trigger symbol.

Noisy signals and glitches

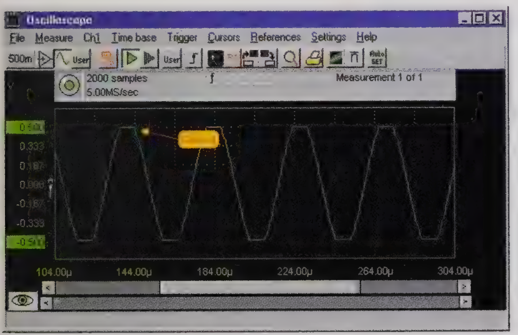
Noisy signals can be "cleaned up" by using Handyprobe's signal averaging feature.

Spotting a glitch on a real-time display is often impossible but TiePie have the bases covered here, too. Envelope mode keeps a record of the highest and lowest samples since last reset and compares these values to each successive sample.

When a sample that exceeds either of these limits is detected, a vertical line is drawn on the display at that point and the value is stored as the new lowest (or highest). Envelope mode can be reset at any user-definable measurement interval – or it can run indefinitely.

Saving settings & waveforms

The good news is that once you've got the instruments set up the way you want for a particular measuring task, you can save those settings to disk for later reuse. And there is no


Oscilloscope

File
Measure
Ch1
Time base
Trigger
Cursors
References
Settings
Help
500m
User
User
Auto SET
2000 samples
5.00MS/sec
Measurement 1 of 1
0.500
0.333
0.167
0.000
-0.167
-0.333
-0.500
104.00µ
144.00µ
184.00µ
224.00µ
264.00µ
304.00µ

Fig.3: the "oscilloscope". Comment balloons provide an easy way of annotating waveforms before printing.

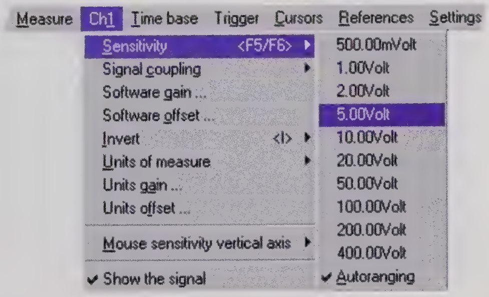

Measure
Ch1
Time base
Trigger
Cursors
References
Settings
Sensitivity <F5/F6>
Signal coupling
Software gain ...
Software offset ...
Invert <I>
Units of measure
Units gain ...
Units offset ...
Mouse sensitivity vertical axis
✓ Show the signal
500.00mVolt
1.00Volt
2.00Volt
5.00Volt
10.00Volt
20.00Volt
50.00Volt
100.00Volt
200.00Volt
400.00Volt
✓ Autoranging

Fig.4: manually setting the input range.

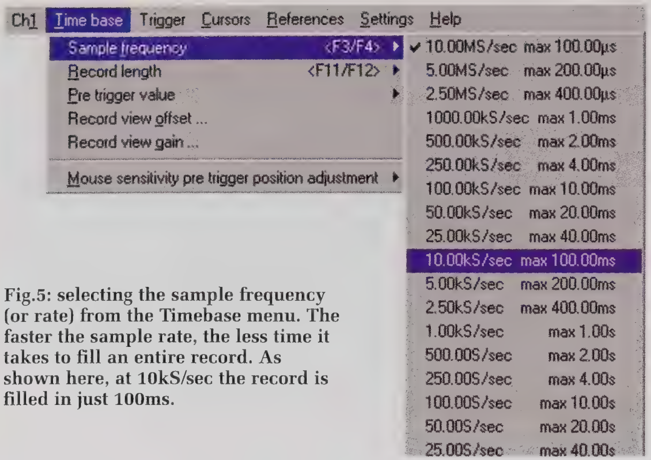

Ch1
Time base
Trigger
Cursors
References
Settings
Help
Sample frequency <F3/F4>
Record length <F11/F12>
Pre trigger value
Record view offset ...
Record view gain ...
Mouse sensitivity pre trigger position adjustment
✓ 10.00MS/sec max 100.00µs
5.00MS/sec max 200.00µs
2.50MS/sec max 400.00µs
1000.00kS/sec max 1.00ms
500.00kS/sec max 2.00ms
250.00kS/sec max 4.00ms
100.00kS/sec max 10.00ms
50.00kS/sec max 20.00ms
25.00kS/sec max 40.00ms
10.00kS/sec max 100.00ms
5.00kS/sec max 200.00ms
2.50kS/sec max 400.00ms
1.00kS/sec max 1.00s
500.00S/sec max 2.00s
250.00S/sec max 4.00s
100.00S/sec max 10.00s
50.00S/sec max 20.00s
25.00S/sec max 40.00s

Fig.5: selecting the sample frequency (or rate) from the Timebase menu. The faster the sample rate, the less time it takes to fill an entire record. As shown here, at 10kS/sec the record is filled in just 100ms.

limit to the number of settings files you can create, either.

Another indispensable feature allows waveforms (both live and reference channels) to be saved on disk for later examination.

Accurate measurements

A variety of useful measurements can be made quickly and easily by using mouse-moveable cursors. These are enabled from the Cursors pulldown menu and once enabled, a dialog box appears, listing all the measurements made at the current cursor positions.

Hard copy

A faithful copy of the displayed waveform can be made at any time by using the Print feature. Comments can be added anywhere on the display area with the aid of user-definable comment balloons.

Balloons can have arrows that point wherever you like (see our "Clipping" balloon example on Fig.3). Balloon shape and colour are customisable, too.

As shown in our example, a longer (up to 3 line) comment can also be added to the top right of the printout.

Voltmeter

In voltmeter mode, data is presented to the user in a similar manner to a conventional digital voltmeter (DVM), and includes triple displays with bargraphs (see Fig.7).

The input signal can be either AC or DC-coupled, with a range of between 0.5 and 400V full scale. Auto-ranging is also supported.

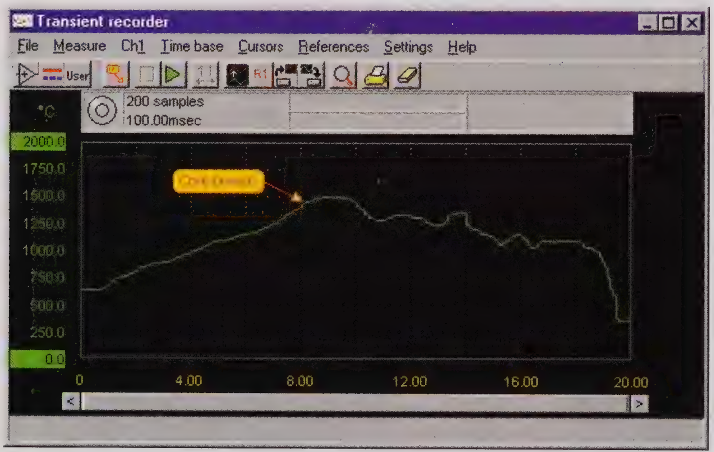

Transient recorder
File
Measure
Ch1
Time base
Cursors
References
Settings
Help
User
R1
°C
200 samples
100.00msec
2000.0
1750.0
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
0
4.00
8.00
12.00
16.00
20.00

Fig.6: the transient recorder instrument. Here we've used the units of measure and units of gain settings to simulate a thermocouple reading in thousands of °C.

Measurements can be made in true RMS, peak-to-peak, mean, maximum, minimum, dBm, power, crest, frequency, duty cycle or instantaneous value.

Quick "go/no-go" tests can be made by configuring the Set high value and Set low value entries appropriately. This function is also useful for monitoring a signal for out-of-range conditions, depending on how the sound settings are configured.

To reduce duplication of settings between instruments, TiePie have slaved many of the settings together. For example, the voltmeter actually uses the record length and post-trigger samples from the oscilloscope.

If either the oscilloscope or spectrum analyser is active though, their settings override the voltmeter settings as the voltmeter has lowest priority. The frequency range setting is an exception to this rule, as changing it in the voltmeter affects all other instruments. TiePie have included a "use scope frequency" setting to avoid potential frustration!

Spectrum analyser

If you work with filters, amplifiers, oscillators, mixers, modulators, or detectors, you need a spectrum analyser. Whereas oscilloscopes display signals in the time domain (which is fine for determining amplitude, time and phase information) spectrum analysers display signals in the frequency domain.

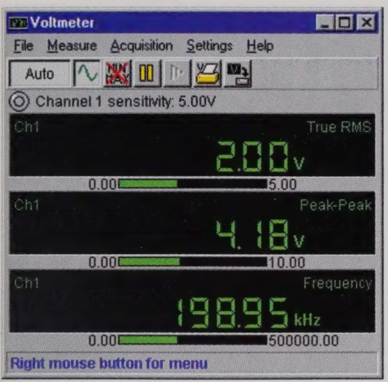
The frequency domain contains certain information that is just not visible in the time domain. To borrow a couple of examples from the Handyprobe user manual:

(1). A sinewave may look good in the time domain but in the frequency domain harmonic distortion is visible.

(2). A noise signal may look totally random in the time domain but in the frequency domain one frequency may be dominantly present.

(3). In the frequency domain, it is easy to determine carrier frequency, modulation frequency, modulation level and modulation distortion from an AM or FM signal.

Fig.8 shows what a 200kHz square wave looks like on the spectrum analyser. Square waves are (theoretically)


Voltmeter
File Measure Acquisition Settings Help
Auto
Right mouse button for menu

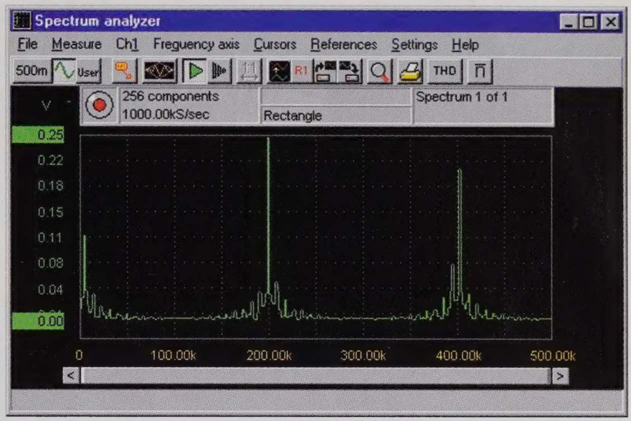
Channel 1 sensitivity: 5.00V

Ch1 True RMS 2.00 V
0.00 5.00

Ch1 Peak-Peak 4.18 V
0.00 10.00

Ch1 Frequency 198.95 kHz
0.00 500000.00

Fig.7: the voltmeter alone can make the Handyprobe an indispensable instrument for service personnel. The readout includes triple digital displays and bargraphs.



256 components
1000.00kS/sec
Rectangle
Spectrum 1 of 1

Fig.8: the spectrum analyser instrument really expands the usefulness of the package.

composed of an infinite number of harmonics, some of which you can see on the left and right of the 200kHz peak.

Without going into complicated explanations, suffice to say that the Handyprobe software uses Fast Fourier Transforms (FFT) to calculate the spectral components of the sampled signal.

Measuring harmonics

An important feature of this instrument is its ability to measure Total Harmonic Distortion (THD). This is set up and displayed from the Measure pull-down menu. The number of harmonics used to calculate the THD is user definable and the results can be displayed in decibels or as a percentage.

As with the oscilloscope, cursors are provided for easy waveform measurement.

A multitude of other features match those that we have already described for the oscilloscope instrument. These include display zooming, signal averaging, copying live to reference memory, saving waveforms to disk, hardcopy output and saving/restoring instrument settings.

Transient recorder

If you need to measure slowly changing signals over a period of time, the transient recorder is the instrument of choice (see Fig.6).

Unlike the other instruments in the package, the transient recorder is direct registering. This means that it displays each measurement as it is made, rather than waiting for an entire record to be acquired. This is necessary because at the lowest sample rate, it can take up to 189.6 days to fill a record!

The different measurement and display techniques used also mean that other instruments cannot be active when the transient recorder is active.

Many features of this instrument are common to those found on the oscilloscope and spectrum analyser, so we'll concentrate mainly on the unique ones here.

Recording speed

Sampling time can be set anywhere from 0.01 second to 500 seconds, with a complete record variable from 1 to 32,760 samples.

The recording process can be interrupted at any time and the results saved to disk or printed. It is also possible to have the recorder run continuously and automatically save to disk at the end of each complete record acquisition.

Note that at very high measuring speeds, TiePie state that some data samples may be lost due to the overhead of disk access.

During recording, the display can be set to roll left as the trace reaches the rightmost edge of the screen – a great feature that reminds me of mechanical chart recorders with their drums and pens.

Data gathered from the recorder will most often be used for documentation purposes, so the vertical axis customisation features really shine in this instrument. Pre-defined choices for the units of measure include Volt, Amp, Degree C, Degree F, Watt, Percent, Metre, Kilogram, Newton, Coulomb, Bar and Hertz.

If you can't find what you want in that lot you can define your own in five characters or less.

Text balloons of variable shape, size and colour can be positioned anywhere on the display and colour printer output is supported, too!

Need more speed?

If the Handyprobe 2 sounds great but you need more bandwidth or another channel, TiePie also offer the TiePieSCOPE HS801. This instrument is not quite as portable as the Handyprobe but it adds a second channel, has five times the sample rate (100M samples/sec) and includes an arbitrary waveform generator (AWG) instrument.

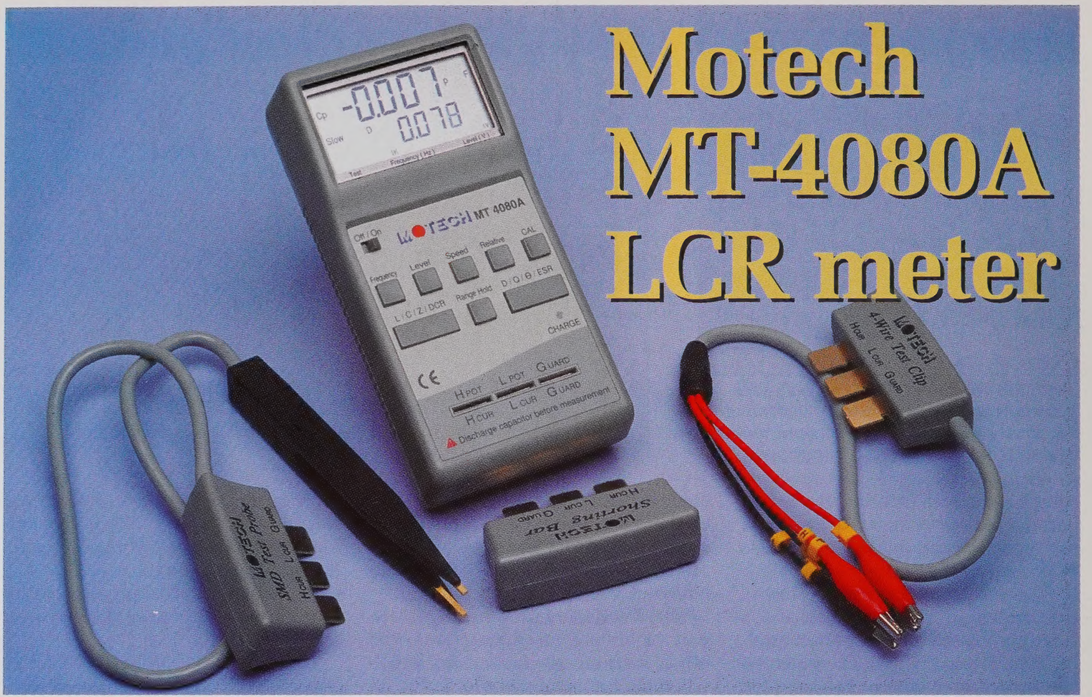
Software for the TiePieSCOPE is practically identical to the Handyprobe, notwithstanding the additional support for the second channel and the AWG.

Where to get it!

Self-running demos and complete user manuals for the Handyprobe 2 and TiePieSCOPE are available for free download from Tiepie's web site at www.tiepie.nl.

Our review unit came from the Australian distributors of TiePie Engineering products, Melbourne-based RTN, phone/fax (03) 9338 3306; email nollet@enternet.com.au. A phone call to RTN will give you the latest pricing. **SC**

Motech MT-4080A LCR meter



Some digital multimeters have facilities for testing inductance, capacitance and resistance but none really do a good job for all three, particularly as far as inductance is concerned. This is where the Motech MT-4080A LCR meter comes into its own.

THE MT-4080A is a multimeter-sized instrument with a large liquid crystal display and eight pushbuttons on its control panel. As well, there is a three-way socket with large contacts to take the measurement adaptors. Of course, some components with suitable leads can be plugged straight in but most component measurements will be taken using one of the adaptors.

All told, up to 10 component parameters can be measured: AC impedance and DC resistance from zero up to 9999MΩ; serial and parallel inductance from 0.000μH up to 9999H; serial and parallel capacitance from 0.000pF to 9999F; equivalent series resistance (ESR) from zero to 9999Ω; Dissipation factor (for capacitors) from 0 to 9999; Quality factor (for inductors) from 0 to 9999; and phase angle from -180° to + 180°.

Not only can all these parameters be measured but you can also use one of five test frequencies: 100Hz, 120Hz, 1kHz, 10kHz and 100kHz. The two lower frequencies are important when measuring ESR of electrolytic capacitors while 100kHz is important when measuring small inductors and dissipation factor in the smaller capacitors. At most times though, the chosen test frequency is likely to be 1kHz.

The test voltage level is also selectable, at 1V, 250mV or 50mV RMS or 1V DC (for DC resistance measurements). Furthermore, if you are making measurements on a component that is varying, you can select fast or slow measurement speeds: 2.5 or 4.5 measurements/second.

The LCD panel will show two parameters for each measurement, plus the signal level and frequency. For example, when measuring a capacitor it will display the capacitance in pF, nF, μF or F (Farads) plus the Dissipation factor or ESR. Similarly, for an inductor, it will display the inductance in μH, mH or H (Henries) plus the Q or ESR.

Accuracy of the MT-4080A is quoted as ±0.2%. The instrument also has a range hold and relative modes which can be handy when selecting components against a standard value.

Two adaptors are available for measurements plus a shorting bar attachment. The first adaptor is a 4-wire probe for surface mount components while the second is a 4-wire probe for testing standard leaded components.

Power comes from two AA cells which may either be alkaline or rechargeable NiMH. A constant current charger is also supplied.

All told then, the Motech MT-4080A is a well-thought out instrument that is very straightforward to use. We used it in our laboratory for several weeks and found it a very reliable unit.

The MT-4080A is priced at $1142 plus GST. For further information, contact Westek Industrial Products, Unit 2, 6-10 Maria Street, Laverton North, 3026. Ph (03) 9369 8802; fax (03) 9369 8006. **SC**

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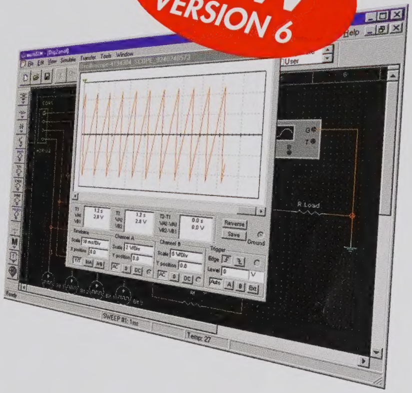

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